THE EFFECT OF KNOWN QUALITY IRRIGATION WATER ON THE CHEMICAL PROPERTIES OF SOILS OF WESTERN KANSAS

by

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LITERATURE REVIEW

Irrigation waters are never pure, they contain some dissolved salts which may vary from just a trace to a concentration so great that the water is not fit for use. During the past fifty years there has been great interest in studying the chemical analysis of irrigation water and its effect on the soil.

Eaton (4) pointed out that the hazard of using water increased as the percent sodium increased above 60 provided the total salt content was low. In this connection McGeorge et.al. (14) increased the exchangeable sodium percentage of the soil on the Arizona Safford Experiment Farm from 10 to near an equilibrium value of 25 by irrigating for a two year period with water having conductivity of 600 micromhos per centimeter and containing about 83 percent sodium. In a study conducted on four different soils in Texas by Longenecker and Lyerly (13), the poorly drained soils of the Lobo Flats area of Texas were irrigated with water that had an electrical conductance of 454 micromhos per centimeter and a sodium content of 66.8 percent. Longenecker and Lyerly (13) reported little difference between the chemical status of virgin and irrigated soil after 5-7 years of cultivation. In another study done on the well drained soils of the Wild Horse area of Texas, water with an electrical conductivity of 1960 micromhos per centimeter and a sodium content of about 62 percent was used for irrigation. Longenecker and Lyerly (13) reported that there was no appreciable increase in soil salinity with depth. Likewise the exchangeable sodium content was not excessively high. In the Pecos Pump area of Texas where water with an electrical conductance of 4390 micromhos per centimeter and sodium content of 48.9 percent was used. Longenecker and Lyerly (13) reported that 15-20 years of irrigation brought about an appreciable higher salt content in the irrigated soils. However in the Dell City area of Texas where water with an electrical conductivity of 2495 micromhos per centimeter and a sodium content of 22.6 percent was used, Longenecker and Lyerly (13) reported a decrease in the salinity of the soil in the top four feet. The leaching of salts was due to:

1. The good drainage system of the soil.

2. The application of water in amounts that exceeded the storage capacity of the root zone. The excess water lost by deep percolation leaches part of the dissolved salts below the root zone where they do not interfere with plant growth.

Lewis and Juve (12) studied 24 well drained Idaho soils which had been irrigated from different sources of water with an electrical conductivity that varied from 100 to 2050 micromhos per centimeter. Except for those soils initially very low in total salt and sodium, the data indicate that the total salt concentration as well as the soluble and the exchangeable sodium of the soil were generally reduced by irrigation. Soluble salts were evenly distributed throughout the profiles of the irrigated soils. In contrast the highest concentration of salts in the non-irrigated soil were found in the lower horizons. Harper (6) found that the soluble salts did not accumulate when the water used for irrigation was low in total salt content. The texture of the 29 soils studied varied from sandy loam to clay loam. In Mesilla Valley, California water containing 592 ppm of dissolved salts (the electrical conductivity of the water was approximately 925* micromhos per centimeter) was used for irrigation. Scofield (15) found that about 8707 tons of salts were leached in a 7 year period when 744,380 acre ft. of this water was used to irrigate 110,000 acres of land.

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* ppm were converted to E.C. x 10^6 by using this formula:
ppm = .64 x E.C. x 10^6.
Classification and Use of Irrigation Waters by L. V. Wilcox. U.S.D.A. Circular No. 969.

In a related study Scofield (15) reported an increase in the salt content of irrigated soils in the Paso Valley, California when water containing 901 ppm of salt was used. Botkin and Shires (1) reported an increase in the soluble salts in Pecos sandy loam which had been irrigated for 37 years from Pecos River water having an electrical conductivity of 5500 micromhos per centimeter. In connection with this study Botkin and Shires (1) reported that the salt content in the Gila adobe soil was decreased by irrigation with Rio Grande River waters which had an electrical conductivity of 780 micromhos per centimeter.

Kelley et.al. (11) reported that the application of irrigation water containing 2 equivalents of sodium to one equivalent of calcium did not produce any important increase in the adsorbed sodium in Yolo clay loam. Under these conditions the absorbed calcium of the soil was increased because of the replacement of magnesium by calcium. However, he stated that under field conditions the evaporation and transpiration of water increases the concentration of the soil solution to such an extent that sodium might start to replace calcium.

Chapman and Kelley (2) reported that when calcareous soils are being investigated, it is not exceptional to find that the amount of calcium dissolved from calcium carbonate by neutral ammonium salts may equal or even exceed the exchangeable calcium. This being the case they concluded that the determination of the exchangeable bases is not a clear-cut and precise method. Kelley (9) also conducted an experiment using neutral ammonium acetate in which 10 to 20 grams of soil were leached with this reagent. He reported that the bases extracted by that procedure exceeded the exchange capacity. Thorne and

Thorne (16) reported that saline water tends to dissolve the calcium carbonate and thus increase the supply of soluble calcium in the soil. This process tends to reduce the amount of sodium that would otherwise be adsorbed from the water. In agreement with the results of Thorne and Thorne, Kelley (9) reported that the absorption of sodium by the soil was diminished by the presence of calcium carbonate. Consequently, Kelley (9) concluded that the absorption of sodium from irrigation water will be substantially less when applied to calcareous soils than to non-calcareous soils.

Eaton (4) reported that calcium and magnesium may precipitate as carbonates if an irrigation water contains more carbonate and bicarbonate than calcium and magnesium and the water becomes sufficiently concentrated. The percent sodium in the soil solution increases in proportion to the amount of precipitation of calcium and magnesium taking place. Eaton used the term "residual sodium carbonate" for that amount of sodium carbonate that would be formed after complete precipitation of the calcium and magnesium had occurred.

Lewis and Juve (12) suggested that if calcium and magnesium are precipitated as carbonates when carbonates and bicarbonates are present, then the equilibrium between soluble and exchangeable ions that might normally be expected is upset.

In contrast to Eaton's conclusion, Thorne and Thorne (16) found no relation between the amount of carbonate and bicarbonate in irrigation water and the amount of lime accumulation. This problem was also studied by Kelley (9) who reported that if chloride is the dominant anion there is little change in the calcium:sodium ratio in the soil solution while if bicarbonate is the dominant anion, then the ratio of calcium to sodium may be altered due to the precipitation of calcium as calcium carbonate if the soil solution becomes sufficiently concentrated.

Lewis and Juve (12) stated that if equilibrium between irrigation waters and soils has been established then there should be a correlation between the sodium adsorption ratio of irrigation water and those of the saturated extract of the soils. This correlation improved in the absence of residual sodium carbonate.

Longenecker and Lyerly (13) stated that equilibrium between soil and water depends on:

a. The type of irrigation. Under row-type irrigation salts are leached from the soil under the furrows but accumulate in the beds due to upward capillary movement of soil moisture and to evaporation. A true equilibrium is thus not likely to be attained between irrigation and the surface soils.

b. The presence of calcium carbonate or gypsum. A true equilibrium between water and soil cannot be attained until these slightly soluble salts are in equilibrium with the irrigation water.

Lewis and Juve (12) did not find any correlation between the sodium adsorption ratio of water used and exchangeable sodium percentage of the soil due in part to low values for both the ratios. On the other hand they reported a high correlation between sodium adsorption ratio of the saturated extract and the exchangeable sodium percentage of the soil. Longenecker and Lyerly (13) also found no significant correlation between the exchangeable sodium percentage and the percent sodium of the water. They reported that the correlation between exchangeable sodium percentage of the soil and the sodium adsorption ratio of irrigation water was not significant due to lack of equilibrium between waters and field soil.

Fireman and Wadleigh (5) reported that the pH of the soil depends on the amount of sodium adsorbed and degree of hydrolysis. Hydrolysis increases the hydroxyl ion activity which in turn increases the pH. Kelley et.al. (11) concluded that the adsorption of the sodium by soil is not directly dependent on pH. However, Eaton (4) found that the pH increases if residual sodium carbonate increases.

According to Thorne and Thorne (16) some waters and soils are well adapted to each other, others are incompatible. Some water of questionable quality can be used on well drained soil without serious harm to the soil, whereas good quality water if used on poorly drained soil can cause a buildup of salt. Because of this, Kelley et.al. (11) warns against adopting a hard and fast line for permissible salinity in irrigation waters.

These and many other studies indicate that irrigation has a definite effect on the chemical properties of soil.

The object of this study was:

a. To determine the chemical characteristics of irrigation water used.

b. To determine the effect of water of known quality on soils under irrigation in Kansas.

SAMPLING

Soil

Well drained soils were sampled in Ford, Gray, Meade, Thomas, Logan, Wallace, Barton, Ellsworth, and McPherson counties. The soils were chosen so that at each site there could be a comparison of the properties of an irrigated and a non-irrigated soil of the same soil type. Where possible, each site was selected so that it would represent the major types of soil being irrigated in the sampling area. Since only sites that were thought to be well drained were selected, it was assumed that any changes in salt, sodium or other chemical constituents could be attributed mainly to the effect of the irrigation water. Figure 1 shows the location of the sampling sites.

The soil at each site was sampled by horizons and the soil described by a Soil Conservation Service Technician. The soil descriptions appear in the

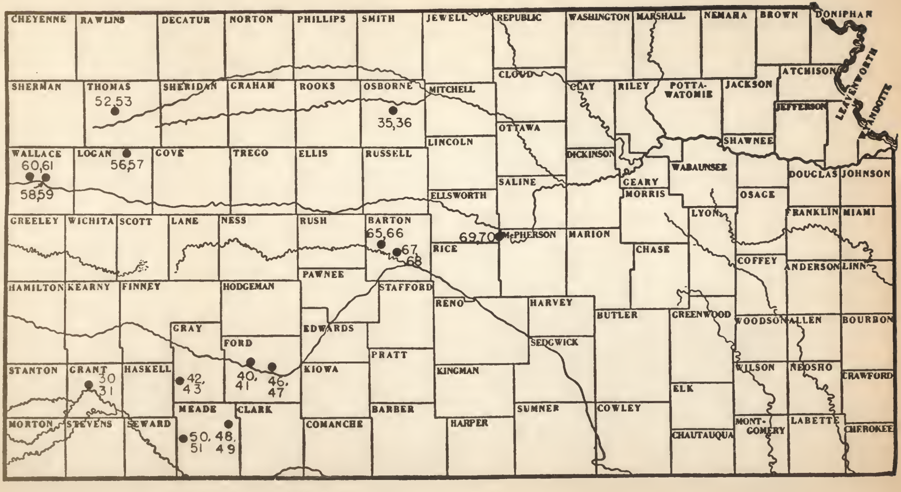

Figure 1. Location of the sites sampled.

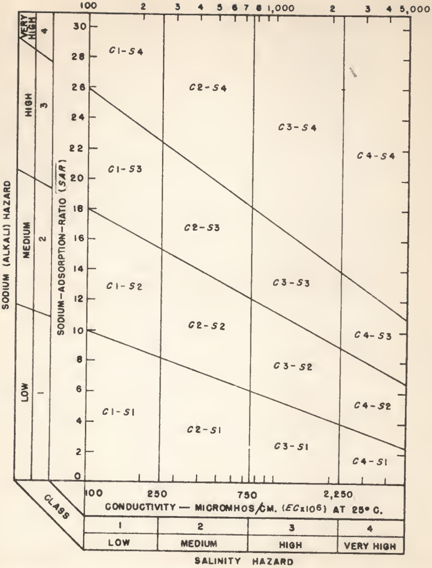

Figure 2. United States Salinity Laboratory diagram for the classification of irrigation waters.

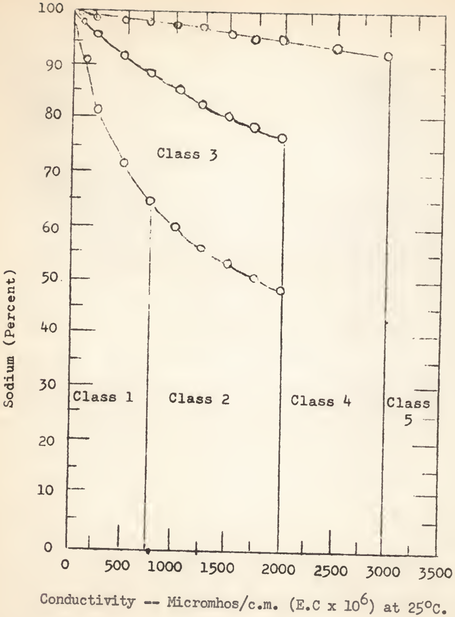

Figure 3. Kansas State University soil testing diagram for classification of irrigation waters. These standards were adapted from those published by Wilcox (19).

appendix in Tables 36 to 63. One and one-half quarts of soil were taken from each horizon. Samples were taken with a 2 inch hydraulic probe where possible. At sites where the hydraulic probe could not be used, the soil was exposed to a depth of 2 to 2½ feet with a spade. Samples were taken from the sides of the exposure by hand. Below the depth of the exposure samples were taken by means of a 3 inch orchard auger. Care was taken to separate the horizons as closely as possible whichever method was used.

Water

Sampling: Water samples were taken directly from the pump discharge for site numbers 30, 40, 42, 46, 48, 50, 52, 57, 58, 60, 65 and 68. Water samples for those sites (35 and 69) irrigated from the Solomon and Smoky Hill rivers were not taken. The analysis of these waters were taken from preliminary water quality reports of the U. S. Geology Survey on file in the Kansas Water Resources Board Offices in Topeka, Kansas. The samples were transported to the laboratory in liter polyethelene bottles and stored under toluene until analyzed.

Classification Standards: Two standards were used to classify irrigation water.

1. The current U. S. Salinity Laboratory Standards.
2. The standards adopted by the Kansas State University Soil Testing Laboratory. These standards were adapted from those published by Wilcox (19).

Figures 2 and 3 show the difference between the two classifications. It is apparent that according to the U. S. Salinity Laboratory Standards more sodium and less total soluble salts are allowed in irrigation water as compared to the standards adopted in Kansas where more soluble salts and less sodium is allowed in irrigation water. For example, in the low salinity, low sodium water the conductivity ranges from 100 to 250 micromhos per centimeter and the sodium adsorption ratio ranges from 8.3 to 10 by U. S. Salinity Laboratory Standards. The maximum exchangeable sodium percentage, estimated from Gapon's equation, that would develop in the soil using this quality water would have a value of approximately 12 percent. In class 1 water by Kansas standards the conductivity of the water ranges up to 750 micromhos per centimeter and the sodium adsorption ratio is below 4.5. The maximum exchangeable sodium percentage, estimated from Gapon's equation, that would develop in the soil using this quality water would have a value of approximately 5 percent.

Under field conditions the exchangeable sodium percentage may ordinarily range from one to two times higher than those predicted by Gapon's equation due to concentration of the salts in the irrigation waters due to evaporation and plant use.

PROCEDURE

Water Analysis

After water samples from sites 30, 40, 42, 46, 48, 50, 52, 57, 58, 60, 65, 68 and 69 were received they were analyzed as follows:

The pH was obtained by use of a Beckman zeromatic pH meter. Electrical conductivity in micromhos per centimeter (E.C. x 10^6) was determined on an Industrial Instruments model RC-BC conductivity bridge with a pipette type conductivity cell. The soluble cations calcium, magnesium, sodium and potassium were determined on a Beckman model D. U. flame photometer with No. 4300 photomultiplier attachment according to the procedure outlined in Jackson (8) and Agriculture Handbook No. 60 (17). The settings used on the flame photometer are listed in Table 1. Determinations were run on all the water samples at one time.

Table 1. Instrument settings on the Beckman flame photometer used in determining water soluble and extractable cations.

Element	Wave Length M.M.	Slit Width	Zero Suppression	Photo Load	Sensitivity	Lever	Acetalene P.S.I.	Oxygen P.S.I.
Ca	556	.1	1	2	2	Out	10	4
Mg	285.5	.06	0 or 1	2	4 or full	Out	10	4
Na	592	.02	1 or 0	2	1	Out	10	4
K	772	.06	1	3	1	In	10	4

Procedures for anion analysis were also obtained from Agriculture Handbook No. 60. The amount of carbonate and bicarbonate ion present was determined by titration with standard sulfuric acid. The amount of chloride ion was determined volumetrically using standard silver nitrate as the titrating solution. The amount of sulfate was determined from electrical conductivity readings. The sulfate was precipitated as calcium sulfate ($CaSO_4$) by adding acetone. The precipitate was then dissolved in water and the conductivity determined. Table 2 shows the analyses of the irrigation water.

Soil Analysis

As soon as the soil samples reached the laboratory the samples were dried and ground in a Braun Pulverizer. The sample was mixed by pulling it on a piece of wrapping paper after which it was replaced in the carton for analysis.

The saturated paste (17) was made by mixing 500 grams of soil and the proper amount of water in a stainless steel beaker. The paste was allowed to stand overnight before extraction. Extraction was accomplished by placing the soil on a Buchner funnel under vacuum. Extraction was continued until the soil cracked.

The pH of the soil was determined on the saturated paste prior to extraction. After extraction the electrical conductivity and the amount of

Table 2. The chemical analyses of the water samples.

Site	$ECx10^6$ [1]	PSSP[2]	pH	K	Ca	Mg	Na	Total	CO_3	HCO_3	Cl	SO_4	Total	SSP[3]	SAR[4]
					m.e./l.					m.e./l.					
30[5]	772	61.5	8.1	.14	2.40	2.3	2.2	7.04	---	3.46	.75	4.1	8.31	31.7	1.40
30[6]	769	53.0	8.3	.12	2.40	2.6	2.2	7.32	---	3.17	.62	4.2	7.99	29.9	1.39
35	613	61.7	7.8	--	3.65	.98	1.5	6.13	---	3.70	.53	1.8	6.03	24.4	.93
40	396	41.2	7.7	.10	2.40	2.0	.70	5.2	---	3.5	.14	.21	3.85	13.5	.4
42	396	47.9	7.8	.11	2.70	1.0	.68	4.49	---	3.07	.11	.49	3.67	14.1	.4
46[7]	565	42.3	7.8	.11	2.90	2.0	1.2	6.21	---	3.37	.36	1.2	4.93	19.3	.8
46[8]	1414	53.0	7.4	1.2	4.30	4.0	4.7	14.2	---	5.33	.98	5.2	11.51	33.1	2.3
48	412	25.6	7.8	.88	2.30	2.1	.70	5.98	---	3.25	.08	.55	3.68	11.7	.4
50	380	58.8	7.9	.08	2.20	1.25	.80	4.33	---	2.97	.09	.49	3.55	18.5	.5
52	460	100	7.8	.30	1.30	1.4	1.1	4.1	---	3.78	.22	.69	4.69	26.8	.9
57	495	100	7.8	.28	1.80	1.65	1.1	4.83	---	4.29	.22	.49	5.0	22.8	.8
58	380	100	7.6	.10	1.30	1.0	1.1	3.50	---	3.11	.09	.49	3.69	31.4	.10
60	383	100	7.9	.10	1.30	1.2	1.0	3.40	---	3.21	.15	.50	3.86	27.8	.8
65-68	990	100	7.2	.30	3.40	1.14	2.85	8.20	---	5.43	3.82	.82	10.07	34.8	1.75
69	650	58.7	7.8	---	3.50	.96	2.7	7.10	---	2.50	2.0	2.6	7.1	38.0	1.80

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[1] Electrical conductivity in micromhos per centimeter.

[2] Percent soluble sodium possible.

[3] Soluble sodium percent.

[4] Sodium adsorption ratio.

[5] New well.

[6] Old well.

[7] Deep well.

[8] Shallow well.

calcium, magnesium, sodium, potassium, chloride, sulfate, carbonate and bicarbonate ions in the saturated extract were determined in the same manner as determined for the water samples. The extract was stored in a 125-milliliter Erlenmeyer flask to which a drop of toluene had been added. A measure of the exchangeable plus the soluble ions was obtained by extracting the soil with neutral 1 N ammonium acetate. Four grams of oven dry soil and 50 milliliters of ammonium acetate were shaken for 15 minutes in half-pint bottles. The extract was then filtered and stored in 125-milliliter Erlenmeyer flasks ready for analysis.

The soluble anions of the saturated extract were determined according to procedures listed in Agriculture Handbook No. 60. The soluble cations in the saturated extract were determined on a Beckman model D. U. flame photometer using the same procedures and standards as were used for the water samples. The cations extracted by ammonium acetate were also determined on a Beckman model D. U. flame photometer. The standard solutions for determining the cations extracted with ammonium acetate were prepared in neutral 1 N ammonium acetate.

The exchangeable cations were determined by subtracting the water soluble cations from the cations extracted with neutral 1 N ammonium acetate. The cation exchange capacity was determined by Method 19, Agriculture Handbook No. 60. The actual exchangeable sodium percent (E.S.P.) was calculated by dividing the exchangeable sodium by the exchange capacity and multiplying by 100. The estimated equilibrium exchangeable sodium percents that would result if the soil and the irrigation water were in equilibrium was calculated according to Gapon's equation (10). The sodium adsorption ratio of the irrigation waters was calculated by the method outlined on page 72 of Agriculture Handbook No. 60.

RESULTS AND DISCUSSION

Water Analysis

The pH of the 16 irrigation waters varied between 8.3 to 7.2. Regression analyses revealed no significant relationship between the amount of sodium in the water and the pH of that water.

The electrical conductivity of the waters varied from 380 to 1414 micromhos per centimeter (E. C. x 10^6). According to the U. S. Salinity Laboratory classifications of waters outlined in Agriculture Handbook No. 60, the waters from site numbers 40, 42, 46 (deep well), 48, 50, 52, 54, 57, 58, 60, 69 are ranked as medium in salinity and low in sodium hazard, whereas waters from sites 30, 46 (shallow well) and 65 are ranked as high in salinity and low in sodium hazard. According to the Kansas State Soil Testing Standards all waters are classified either class 1 or class 2. Table 2 shows that the waters used at site numbers 52, 57, 58, 60 and 65 contain sufficient bicarbonate to precipitate all of the calcium and magnesium in the irrigation water provided the water is concentrated sufficiently.

If precipitation occurs then the amount of calcium and magnesium in the soil solution decreases and the percent sodium in the soil solution increases, thus constituting an increased hazard in the use of these waters for irrigation. Eaton (4) suggests that if the percent sodium in a well drained soil exceeds 60 percent, then significant amount of exchangeable sodium may be adsorbed by the soil. Data in Figure 4 indicates that when irrigation water with a low $\frac{Ca+Mg}{Na}$ ratio is used to irrigate calcareous soils, the $\frac{Ca+Mg}{Na}$ ratio in the saturated extract of the soil increases denoting that calcium in the soil is being dissolved. On the other hand, if the irrigation water contained a high ratio of $\frac{Ca+Mg}{Na}$ then the ratio of $\frac{Ca+Mg}{Na}$ in the saturated extract decreased,

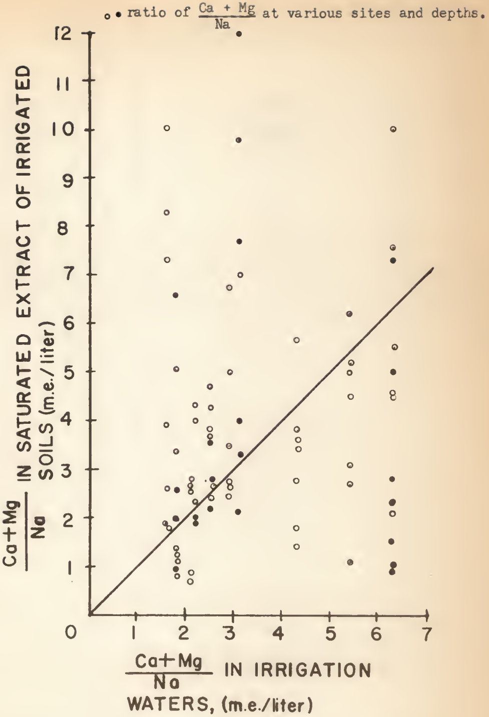

Figure 4. A comparison of the $\frac{Ca + Mg}{Na}$ ratio in irrigation water and in the saturated extract of the irrigated soil. The line through the origin represents the condition that would prevail if the $\frac{Ca + Mg}{Na}$ ratio in the irrigation water equaled that in the soil saturated extract.

denoting that a partial precipitation of calcium had been taking place. In this study, the waters containing residual sodium carbonate were relatively low in salt as well as in the ratio of $\frac{Ca+Mg}{Na}$. Calcium and magnesium were dissolved from the soil rather than being precipitated from the water when these waters were used for irrigation.

Soil Analysis

Since most statistical tests could not be applied because of the limited number of observations, the changes taking place at each site will be discussed individually.

Keith Silt Loam, Sites 52, 53, 56, 57, 58, 59, 60 and 61. Four of the sampling areas chosen were located on Keith silt loam soil. Sites 52 and 53 were sampled from F. Rickroff farm in Thomas county, sites 56, 57 were sampled from B. Lee farm in Logan County, sites 58, 59 were sampled from W. Turner farm and sites 60, 61 were sampled from the W. Mai farm, both in Wallace County. The chemical analyses of the irrigated and non-irrigated sites are found in Tables 3, 4, 5, 6, 7, 8, 9, and 10. The soil survey descriptions are found in Tables 36 to 43 in the appendix.

The irrigation water used on each of the irrigated soils was very similar. Table 2 shows that the electrical conductivity of the four waters ranged from 380 to 495 micromhos per centimeter. The sodium adsorption ratio of the water varied only from 0.8 to 1.0 and the soluble sodium varied from 22.8 to 31.4 percent. All the waters would be classed as low in sodium and medium in salinity hazard by U. S. Salinity Laboratory Staff (17) and as class 1 by the Kansas State University Soil Testing Standards.

In 1950 Eaton (4) suggested that calcium and magnesium could be precipitated in waters which contained carbonate and bicarbonate, if the waters

Table 3. A comparison of the chemical properties of irrigated and non-irrigated Keith silt loam soil located in Thomas County.

Depth in inches	Saturation Percentage	Conductivity $EC \times 10^3$	pH	Exchangeable cations in m.e. per 100 gr. of soil				Exchangeable Na percentage	Percent of Calcium Carbonate	Exchange Capacity m.e./100 gr. soil	Gypsum content
				K	Ca	Mg	Na				
	Location:	N.E. ¼ Sec. 7, T 7S, R 32 W						Site 52 irrigated for 18 years			
0-6	47.1	.87	7.8	1.48	18.56	5.28	.32	1.16	--	27.5	--
6-16	36.3	1.09	7.8	1.45	18.50	5.23	.31	1.22	--	25.5	--
16-24	41.9	.87	7.7	1.71	47.11	6.63	.32	1.0	3.95	32.0	--
24-52	36.7	.51	8.2	2.26	60.96	7.28	.23	.79	8.03	29.0	--
52-60	37.3	.45	8.2	2.44	44.96	5.93	.35	1.21	5.51	29.0	--
	Location:	S.E. ¼ Sec. 7, T 7S, R 32 W						Site 53 non-irrigated			
0-7	42.0	.600	8.2	1.82	15.88	5.28	.12	.60	--	20.0	--
7-17	46.7	.640	8.0	1.75	17.61	6.13	.12	.46	--	26.0	--
17-23	47.3	.640	7.8	1.95	52.36	5.52	.11	.37	8.00	30.0	--
23-50	39.0	.459	8.1	2.50	51.71	7.70	.24	.84	9.61	28.5	--
50-64	42.8	.537	8.2	2.81	42.71	6.71	.54	1.96	6.50	27.5	--

Table 4. A comparison of the cations and anions in the saturated extract of irrigated and non-irrigated Keith silt loam soil located in Thomas County.

Depth in inches	Water soluble ions m.e./100 gr. soil									
	Cations					Anions				
	K	Ca	Mg	Na	Total	CO_3	HCO_3	Cl	SO_4	Total
					Site 52 irrigated					
0-6	.04	.19	.09	.06	.38	-	.35	.04	.11	.50
6-16	.05	.25	.14	.09	.53	-	.40	.11	.19	.70
16-24	.04	.14	.12	.06	.36	-	.14	.21	.06	.41
24-52	.04	.04	.08	.05	.21	-	.09	.02	.01	.11
52-60	.05	.04	.07	.03	.19	-	.09	.02	.05	.16
					Site 53 non-irrigated					
0-7	.05	.12	.09	trace	.26	-	.23	.02	.06	.31
7-17	.05	.14	.12	trace	.31	-	.22	.07	.06	.35
17-23	.07	.14	.10	.02	.33	-	.23	.06	.11	.40
23-50	.05	.04	.05	.04	.18	-	.08	.04	.01	.13
50-64	.06	.04	.04	.09	.23	-	.10	.03	.10	.23

Table 5. A comparison of the chemical properties of irrigated and non-irrigated Keith silt loam soil located in Logan County.

Depth in inches	Saturation Percentage	Conductivity $EC \times 10^3$	pH	Exchangeable cations in m.e. per 100 gr. of soil				Exchangeable Na percentage	Percent of Calcium Carbonate	Exchange Capacity m.e./100 gr. soil	Gypsum content
				K	Ca	Mg	Na				
	Location:	S.W. ¼ Sec. 19, T 11S, R 33 W						Site 57 irrigated for 12 years			
0-8	39.3	1.461	7.9	1.67	15.53	4.78	.19	.84	1.2	22.5	--
8-16	42.4	.449	8.0	1.47	15.16	5.32	.10	.51	1.96	19.5	--
16-26	40.2	.974	8.0	1.27	17.27	4.92	.49	1.98	2.07	24.8	--
26-36	41.3	1.299	8.1	1.48	28.20	5.88	.24	.87	2.77	27.5	--
36-49	41.9	.418	8.2	1.64	54.72	6.82	.11	.40	8.70	27.5	--
49-60	42.1	.763	7.8	1.94	49.34	6.78	.24	.92	6.02	26.0	--
	Location:	S.W. ¼ Sec. 19, T 11S, R 33 W						Site 56 non-irrigated			
0-6	37.8	.698	8.2	2.04	12.39	3.78	.11	.60	--	18.5	--
6-12	41.0	.563	8.3	1.71	14.89	4.92	.20	.87	--	23.0	--
12-22	44.8	.713	8.1	1.71	18.59	5.51	.10	.43	--	23.0	--
22-28	42.4	.698	7.9	1.95	53.87	5.91	.19	.60	4.73	31.5	--
28-47	37.9	.430	8.0	2.45	49.46	5.31	.18	.65	4.52	27.5	--
47-60	37.6	.520	8.4	2.95	30.72	4.97	.68	2.38	--	28.5	--

Table 6. A comparison of the cations and anions in the saturated extract of irrigated and non-irrigated Keith silt loam soil located in Logan County.

Depth in inches	Water soluble ions m.e./100 gr. soil									
	Cations					Anions				
	K	Ca	Mg	Na	Total	CO_3	HCO_3	Cl	SO_4	Total
					Site 57 irrigated					
0-8	.08	.37	.22	.06	.73	-	.65	.02	.29	.96
8-16	.03	.09	.05	.02	.19	-	.15	.02	.08	.25
16-26	.03	.23	.08	.01	.35	-	.16	.19	.03	.38
26-36	.04	.29	.12	trace	.45	-	.08	.38	.06	.52
36-49	.03	.07	.05	trace	.15	-	.09	.01	.08	.18
49-60	.06	.16	.09	trace	.31	-	.17	.01	.08	.26
					Site 56 non-irrigated					
0-6	.08	.11	.09	.02	.30	-	.24	.03	.09	.36
6-12	.04	.11	.08	.03	.26	trace	.17	.03	.07	.27
12-22	.04	.16	.11	.03	.34	-	.20	.11	.11	.42
22-28	.05	.13	.09	.01	.28	-	.09	.16	.05	.30
28-47	.05	.04	.05	.02	.16	-	.09	.02	.08	.19
47-60	.05	.03	.03	.07	.18	trace	.11	.02	.07	.20

Table 7. A comparison of the chemical properties of irrigated and non-irrigated Keith silt loam soil located in Wallace County.

Depth in inches	Saturation Percentage	Conductivity ECx10^3	pH	Exchangeable cations in m.e. per 100 gr. of soil				Exchangeable Na percentage	Percent of Calcium Carbonate	Exchange Capacity m.e./100 gr. soil	Gypsum content
				K	Ca	Mg	Na				
	Location:	SW$\frac{1}{4}$, Sec. 6, T 15S, R 39 W						Site 58 irrigated 8 years			
0-8	43.5	.585	8.1	1.17	13.65	8.06	.31	1.59	1.39	19.5	--
8-16	45.6	.557	7.9	1.30	20.14	9.93	.48	1.68	4.87	28.5	--
16-25	45.5	.461	8.2	1.59	52.42	13.94	.32	.93	6.77	34.5	--
25-32	44.0	.480	8.0	2.03	50.19	13.69	.57	1.73	8.47	33.0	--
32-44	39.5	.585	8.1	1.97	51.71	9.96	.66	2.44	10.69	27.0	--
44-56	38.6	.548	8.1	1.84	49.47	9.97	.66	2.44	9.74	27.0	--
	Location:	1600' E and 500' N of S. E. Sec. 6 - 15 - 39							Site 59 non-irrigated		
0-7	47.6	.605	8.1	1.29	18.09	9.4	.11	.40	2.08	27.5	--
7-15	46.0	.731	8.0	1.49	46.34	11.9	.23	.67	2.25	34.5	--
15-22	44.1	.449	8.2	1.72	52.42	14.69	.34	1.01	9.38	33.5	--
22-30	42.8	.474	8.0	1.77	51.71	14.71	.54	1.80	11.01	30.0	--
30-42	34.6	.586	8.2	1.78	48.73	9.98	1.04	3.78	10.51	27.5	--
42-54	38.6	.675	8.3	1.64	46.46	8.97	1.0	3.70	9.12	27.0	--

Table 8. A comparison of the cations and anions in the saturated extract of irrigated and non-irrigated Keith silt loam soil located in Wallace County

Depth in inches	Water soluble ions m.e./100 gr. soil									
	Cations					Anions				
	K	Ca	Mg	Na	Total	CO_3	HCO_3	Cl	SO_4	Total
					Site 58 irrigated					
0-8	.03	.10	.06	.06	.25	-	.23	.03	.07	.33
8-16	.02	.11	.07	.07	.27	-	.21	.01	.07	.29
16-25	.03	.08	.06	.05	.22	-	.14	.01	.09	.24
25-32	.04	.06	.06	.05	.21	-	.13	.01	.08	.22
32-44	.03	.04	.04	.09	.20	-	.11	.02	.10	.23
44-56	.03	.03	.03	.09	.18	-	.09	.02	.08	.19
					Site 59 non-irrigated					
0-7	.03	.16	.10	.01	.30	-	.26	.01	.09	.36
7-15	.03	.16	.10	.02	.31	-	.15	.13	.08	.36
15-22	.03	.08	.06	.03	.20	-	.14	.01	.07	.22
22-30	.03	.04	.04	.08	.19	-	.11	.01	.07	.19
30-42	.02	.02	.02	.11	.17	-	.08	.01	.05	.14
42-54	.03	.04	.03	.15	.25	-	.09	.02	.06	.17

Table 9. A comparison of the chemical properties of irrigated and non-irrigated Keith silt loam soil located in Wallace County.

Depth in inches	Saturation Percentage	Conductivity $ECx10^3$	pH	Exchangeable cations in m.e. per 100 gr. of soil K	Ca	Mg	Na	Exchangeable Na percentage	Percent of Calcium Carbonate	Exchange Capacity m.e./100 gr. soil	Gypsum content
	Location:	E½, Sec. 7, T 15S, R 39 W						Site 60 irrigated for 10 years			
0-10	43.3	.675	8.1	1.34	31.33	6.81	.32	1.16	3.51	27.5	--
10-17	44.8	.531	8.1	1.34	26.12	6.82	.32	1.17	2.72	30.5	--
17-24	41.8	.626	8.4	1.39	46.38	9.45	.31	.97	4.48	32.0	--
24-29	41.3	.675	8.4	1.61	51.64	9.94	.44	1.30	6.12	32.0	--
29-51	46.0	.501	8.2	1.63	53.94	14.70	.70	2.54	12.12	27.5	--
51-60	40.9	.531	8.1	1.71	50.95	19.94	.45	1.76	10.28	25.5	--
	Location:	E½, Sec. 7, T 15S, R 39 W						Site 61 non-irrigated			
0-11	48.5	.422	7.7	1.64	38.62	4.04	.24	.67	4.13	35.5	--
11-19	47.2	.361	7.8	2.22	56.19	5.32	.35	.99	6.99	35.5	--
19-26	45.0	.409	7.9	2.88	76.07	5.31	.33	1.00	5.77	33.0	--
26-31	43.1	.450	8.0	3.11	47.46	5.97	.66	2.16	5.04	30.5	--
31-37	39.5	.506	8.1	2.72	49.97	4.84	.88	3.52	8.95	25.0	--
37-56	38.5	.554	8.2	2.44	48.73	4.09	1.10	4.58	10.80	24.0	--
56-63	39.7	.587	8.1	2.34	47.48	3.97	1.33	5.54	9.06	24.0	--

Table 10. A comparison of the cations and anions in the saturated extract of irrigated and non-irrigated Keith silt loam soil located in Wallace County.

Depth in inches	Water soluble ions m.e./100 gr. soil									
	Cations					Anions				
	K	Ca	Mg	Na	Total	CO_3	HCO_3	Cl	SO_4	Total
					Site 60 irrigated					
0-10	.03	.17	.06	.05	.31	-	.26	.01	.17	.44
10-17	.03	.13	.05	.05	.26	-	.17	trace	.15	.32
17-24	.03	.12	.05	.06	.26	.04	.12	.05	.15	.36
24-29	.04	.11	.06	.06	.27	.03	.12	.03	.15	.33
29-51	.04	.06	.05	.05	.20	-	.10	.01	.08	.19
51-60	.04	.05	.06	.05	.20	-	.08	.01	.05	.14
					Site 61 non-irrigated					
0-11	.03	.13	.08	.01	.25	-	.20	.01	.09	.30
11-19	.03	.07	.05	.02	.17	-	.14	.01	.09	.24
19-26	.04	.05	.06	.04	.19	-	.13	trace	.09	.22
26-31	.04	.04	.03	.09	.20	-	.13	trace	.09	.22
31-37	.03	.03	.03	.12	.21	-	.12	trace	.09	.21
37-56	.03	.02	.03	.15	.23	-	.09	trace	.10	.19
56-63	.03	.02	.02	.17	.24	-	.11	.01	.13	.25

become sufficiently concentrated. If the amount of carbonate and bicarbonate ions exceeded the amount of calcium and magnesium ions present then it would be theoretically possible to precipitate all of the calcium and magnesium and increase the soluble sodium to 100 percent. Note that the water used on all four irrigated sites contains more bicarbonate than calcium and magnesium and hence it would be possible to have 100 percent sodium in these waters if all the calcium and magnesium precipitated.

Eaton (4) suggested also that appreciable sodium will not be adsorbed by the exchange complex unless the soil contains 60 percent or more soluble sodium. The U. S. Salinity Laboratory puts the figure at 50 percent. Table 11 gives a summary of the water and soil analyses pertaining to these four sites

Table 11. A comparison of the mean electrical conductivity and sodium content of the soil and water at the Keith silt loam sites.

Site Numbers	Years of Irrigation	Soil Analysis Means				Irrigation Water Analysis		
		Irrigated		Non-irrigated				
		E.S.P.	$ECx10^3$	E.S.P.	$ECx10^3$	$ECx10^6$	S.A.R.	Percent Sodium
52-53	18	1.00	.68	.96	.54	460	.9	26.8
57-56	12	.91	.86	1.00	.56	495	.8	22.8
58-59	8	1.82	.53	2.21	.60	380	1.0	31.4
60-61	10	1.75	.57	3.0	.48	388	.8	27.8

E.S.P. - Exchangeable sodium percentage.
$ECx10^3$ - Electrical conductivity in millimhos.
$ECx10^6$ - Electrical conductivity in micromhos.
S.A.R. - Sodium adsorption ratio.

The exchangeable sodium percent and the electrical conductivity in Table 11 are weighted means determined from the data given in Tables 3, 5, 7, 8, and 9.

Salt Content. The electrical conductivity of the saturated extract was increased slightly in site numbers 52, 56 and 60. The maximum increase was from a mean of .560 in the non-irrigated soil to a mean of .860 millimhos per centimeter in the irrigated site. The electrical conductivity of site 58 decreased upon irrigation from a mean of .60 in the non-irrigated soil to .53 millimhos per centimeter in the irrigated soil. The water soluble calcium increased in sites numbers 52, 56, and 60 from a mean of .27 in the non-irrigated soil to .44 m.e. per 100 grams in the irrigated soil. The maximum increase was .33 m.e. per 100 grams of soil. No change of soluble calcium was observed between the irrigated and non-irrigated soil in site numbers 58 and 59. The water soluble magnesium increased in site numbers 52 and 60 from a mean of .05 in the non-irrigated soil to .07 m.e. per 100 grams of soil in the irrigated site. The maximum increase of magnesium was .02 m.e. per 100 grams of soil. No change of soluble magnesium was observed in the irrigated and non-irrigated site numbers 58 and 59. In site 56 the soluble magnesium decreased from a mean of .10 in the non-irrigated soil to .07 m.e. per 100 grams in the irrigated soil.

Sodium Content. Table 11 indicates that irrigation reduced the exchangeable sodium percentage slightly in three out of four soils. The maximum decrease was 1.25 percent. In the irrigated and non-irrigated site numbers 52 and 53, the exchangeable sodium was 1.00 and .96 percent respectively, indicating a very slight increase.

In the non-irrigated Keith silt loam soils the highest concentration of sodium was without exception in the lower horizons. Irrigation in each case tended to reduce the percent sodium in the lower horizons and to increase the percent sodium in the upper horizons.

Table 12 shows the percent sodium in the surface horizon and in the deepest subsurface horizon for these four irrigated and non-irrigated soils. The mean sodium content of the surface increased from .58 to 1.18 percent after irrigation. In the deepest subsurface horizon sampled, the percent exchangeable sodium decreased from a mean of 3.4 in the non-irrigated soils to a mean of 1.58 percent in the irrigated soils. The data support the idea that the sodium content in each soil is approaching equilibrium with the water applied.

Table 12. A comparison of the exchangeable sodium percent in irrigated and non-irrigated sites of the Keith silt loam in the topmost and lowest horizons sampled.

Horizons	Site Numbers	Years of Irrigation	Exchangeable Sodium Percent	
			Non-irrigated	Irrigated
Surface Horizon	52-53	18	.6	1.16
	57-56	12	.6	.84
	58-59	8	.4	1.59
	60-61	10	.67	1.16
		Weighted Mean	.58	1.18
Deepest Horizon	52-53	18	1.96	1.21
	57-56	12	2.38	.92
	58-59	8	3.70	2.44
	60-61	10	5.54	1.76
		Weighted Mean	3.08	1.57

The following conclusions can be drawn from the data:

1. In the subsoil the percent sodium was above the equilibrium value and hence the percent exchangeable sodium decreased with irrigation.
2. In the surface soil the percent sodium was below the equilibrium value and hence the percent exchangeable sodium was increased by the application of irrigation water.
3. The percent sodium in the surface will likely approach closely the percent sodium in the subsoil if the soil is irrigated for a sufficient length of time under conditions of adequate drainage.
4. The equilibrium percent sodium in these soils will likely be less than 1.6 percent when irrigated with waters of comparable quality.

It is evident that little if any precipitation of calcium and magnesium is taking place since the saturated extract of the irrigated soil contains an average of 19.3 percent sodium as compared to an average sodium percent of 27.2 for the irrigation water added.

Harney Silt Loam, Sites 40, 41, 42 and 43. Two of the sampling areas chosen were located on Harney silt loam soils. Sites 40 and 41 were sampled from H. Spohr farm in Ford County, whereas sites 42 and 43 were sampled from W. Josserand farm in Gray County. The chemical analyses of the soil are found in Tables 13, 14, 15 and 16. The soil survey descriptions are found in Tables 44 to 47 in the appendix.

Table 2 shows that the waters used on both the sites are very similar. The electrical conductivity and the sodium adsorption ratio are the same for the two sites, 396 micromhos per centimeter and .4 respectively. The soluble sodium content in waters of sites 40 and 42 is 13.5 and 14.1 percent respectively. According to the U. S. Salinity Laboratory Standards, the two waters would be classified medium in salinity and low in sodium hazard. By Kansas State University Testing Standards the two waters are ranked as class 1 water.

Salt Content. The mean electrical conductivity of the non-irrigated sites 41 and 43 was .532 and .736 millimhos per centimeter respectively. Irrigation for 13 and 8 years increased the mean electrical conductivity to .696 and .843 millimhos per centimeter in the irrigated sites 40 and 42 respectively. Data in Table 14 indicate that there was no increase in the soluble calcium and magnesium in the irrigated and non-irrigated soil of sites 40 and 41. The soluble calcium and magnesium increased from a mean of .10 and .14 m.e. per 100 grams in the non-irrigated soil of site 43 to .19 and .18 m.e. per 100 grams in the irrigated site 42 respectively.

Sodium Content. The data for the Harney silt loam was similar to that of the Keith silt loam soils in that the mean exchangeable sodium percentage

Table 13. A comparison of the chemical properties of irrigated and non-irrigated Harney silt loam soil located in Ford County.

Depth in inches	Saturation Percentage	Conductivity ECx10^3	pH	Exchangeable cations in m.e. per 100 gr. of soil K	Ca	Mg	Na	Exchangeable Na percentage	Percent of Calcium Carbonate	Exchange Capacity m.e./100 gr. soil	Gypsum content
Location:	.25 mi. N & .1 mi. W of S¼, Sec. 5, T 28S, R 24 W corner								Site 40 irrigated for 13 years		
0-5	47.3	1.100	7.2	1.40	11.82	3.58	.01	.01	1.85	15.0	--
5-10	54.6	.825	7.4	1.17	15.96	4.87	.14	.66	5.01	21.0	--
10-16	55.7	.707	7.5	.98	20.44	4.96	.09	.35	6.01	25.5	--
16-24	57.2	.660	7.4	1.04	22.58	4.95	.06	.24	2.65	25.5	--
24-36	54.2	.600	7.7	1.08	22.87	4.94	.34	1.48	2.85	23.0	--
36-47	52.6	.683	7.6	1.23	28.76	5.46	.09	.46	4.42	19.5	--
47-60	56.7	.609	7.5	1.04	26.15	5.45	.24	1.33	3.58	18.0	--
Location:	.1 mi. N and 50'E of S¼, Sec. 5, T 28S, R 24 W corner								Site 41 non-irrigated		
0-6	46.3	.605	7.3	1.39	9.85	3.04	.04	.25	1.89	16.0	--
6-11	50.6	.121	7.8	1.08	16.31	4.85	.07	.32	1.67	21.5	--
11-18	57.8	.176	7.8	1.09	20.86	5.44	.40	1.40	2.35	28.5	--
18-28	65.1	.363	7.6	1.35	26.14	5.45	3.24	11.17	2.91	29.0	--
28-35	60.8	.605	7.9	1.60	32.90	5.46	1.02	3.77	4.30	27.0	--
35-46	53.8	.605	8.3	1.42	30.31	5.46	1.35	5.00	3.59	27.0	--
46-58	56.1	.907	7.3	1.42	31.04	5.17	1.70	6.41	3.25	26.5	--

Table 14. A comparison of the cations and anions in the saturated extract of irrigated and non-irrigated Harney silt loam soil located in Ford County.

Depth in inches	Water soluble ions m.e./100 gr. soil									
	Cations					Anions				
	K	Ca	Mg	Na	Total	CO_3	HCO_3	Cl	SO_4	Total
					Site 40 irrigated					
0-5	.04	.18	.09	.06	.37	-	.52	.04	.05	.61
5-10	.03	.16	.07	.05	.31	-	.31	.04	.08	.43
10-16	.02	.18	.04	.04	.28	-	.28	.02	.07	.37
16-24	.02	.17	.05	.03	.27	-	.24	.01	.06	.31
24-36	.02	.14	.06	.02	.28	-	.17	.01	.03	.21
36-47	.02	.11	.06	.04	.23	-	.15	.03	.06	.24
47-60	.02	.10	.05	.07	.24	-	.13	.03	.14	.30
					Site 41 non-irrigated					
0-6	.05	.16	.08	.04	.33	-	.29	.05	.11	.45
6-11	.02	.19	.09	.06	.36	-	.29	.04	.11	.44
11-18	.01	.16	.06	.09	.32	-	.26	.04	.11	.41
11-28	.03	.11	.05	.13	.32	-	.26	.04	.15	.45
28-35	.03	.10	.04	.23	.40	-	.27	.02	.12	.41
35-46	.02	.06	.04	.21	.33	-	.17	.05	.02	.24
46-58	.02	.17	.08	.30	.57	-	.13	.24	.16	.53

Table 15. A comparison of the chemical properties of irrigated and non-irrigated Harney silt loam soil located in Gray County.

Depth in inches	Saturation Percentage	Conductivity $EC \times 10^3$	pH	Exchangeable cations in m.e. per 100 gr. of soil				Exchangeable Na percentage	Percent of Calcium Carbonate	Exchange Capacity m.e./100 gr. soil	Gypsum content
				K	Ca	Mg	Na				
Location:	NE¼, Sec. 5, T 28S, R 30W							Site 42 irrigated for 8 years			
0-6	46.7	.712	8.1	1.64	15.15	4.56	.01	.03	1.53	30.0	--
6-9	49.2	.574	8.3	1.29	16.35	4.71	.07	.32	1.37	21.4	--
9-13	50.0	.556	8.4	1.21	20.09	6.39	.06	.27	--	25.9	--
13-18	50.5	.523	8.1	.99	19.35	6.44	.07	.13	2.22	30.0	--
18-26	55.8	.685	8.3	.91	34.35	6.43	-	-	5.28	27.0	--
26-35	55.4	.371	8.3	1.29	32.93	6.66	.07	.26	4.99	27.0	--
35-58	59.2	1.271	8.0	2.01	27.85	9.09	.04	.12	2.93	33.0	--
Location:	300' S, 100' W from NE corner of NW¼, Sec. 5, T 28 S, R 30 W								Site 43 non-irrigated		
0-5	48.1	.636	7.8	1.82	12.21	4.55	.03	.14	1.16	21.4	--
5-10	51.8	.324	7.8	1.37	15.68	6.47	.01	.04	1.50	22.5	--
10-17	56.2	.434	7.7	1.67	17.89	7.39	.02	.07	1.90	28.4	--
17-25	51.1	.494	8.3	1.73	29.41	7.76	.07	.27	2.45	25.9	--
25-32	51.6	.890	8.1	1.72	30.99	9.20	.07	.25	5.41	27.0	--
32-36	49.1	.680	8.3	2.03	30.31	8.90	.25	.97	4.74	25.9	--
36-50	56.9	1.148	8.0	2.07	30.65	9.93	.13	.37	3.88	35.0	--

Table 16. A comparison of the cations and anions in the saturated extract of irrigated and non-irrigated Harney silt loam soil located in Gray County.

Depth in inches	Water soluble ions m.e./100 gr. soil									
	Cations					Anions				
	K	Ca	Mg	Na	Total	CO_3	HCO_3	Cl	SO_4	Total
					Site 42 irrigated					
0-6	.04	.18	.13	.05	.40	-	.26	.04	.17	.47
6-9	.02	.15	.16	.06	.39	trace	.22	.04	.20	.46
9-13	.03	.18	.17	.07	.45	trace	.27	.11	.14	.52
13-18	.02	.15	.12	.06	.35	-	.21	.02	.14	.37
18-26	.03	.15	.13	.09	.40	trace	.19	.12	.18	.49
26-35	.02	.07	.09	.06	.24	trace	.11	.01	.16	.28
35-58	.05	.27	.28	.09	.69	-	.10	.60	.05	.75
					Site 43 non-irrigated					
0-5	.05	.16	.14	.02	.37	-	.25	.06	.13	.44
5-10	.02	.07	.09	.02	.20	-	.15	.04	.04	.23
10-17	.02	.11	.11	.04	.28	-	.15	.08	.04	.27
17-25	.03	.09	.11	.06	.29	-	.19	.06	.02	.27
25-32	.04	.13	.17	.12	.46	-	.10	.31	.01	.42
32-36	.03	.06	.10	.12	.31	-	.07	.13	.04	.24
36-50	.07	.10	.19	.37	.73	-	.43	.04	.46	.93

in the soil was reduced due to irrigation. Table 17 shows that irrigation of site 40 reduced the mean exchangeable sodium percentage from a mean of 4.88 to .79 and irrigation of site 42 reduced the exchangeable sodium percentage from a mean of .29 to .14. It appears that the equilibrium exchangeable sodium percent of these soils will be less than .6 percent when irrigated with water of this quality provided leaching is adequate.

Table 17. A comparison of the mean sodium content and electrical conductivity of the irrigation water and the soil at the irrigated and non-irrigated Harney silt loam sites.

Site Numbers	Years of Irrigation	Soil Analysis Means				Irrigation Water Analysis		
		Irrigated		Non-irrigated				
		E.S.P.	$ECx10^3$	E.S.P.	$ECx10^3$	$ECx10^6$	S.A.R.	Percent Sodium
40-41	13	.79	.696	4.88	.532	396	.4	13.5
42-43	8	.14	.843	.29	.736	396	.4	14.1

E.S.P. - Exchangeable sodium percentage.
$ECx10^3$ - Electrical conductivity in millimhos.
$ECx10^6$ - Electrical conductivity in micromhos.
S.A.R. - Sodium adsorption ratio.

The water soluble sodium in the non-irrigated site 41 was 1.07 m.e. per 100 grams of soil. Irrigation for 8 years decreased this value to .31 m.e. per 100 grams. Site 42 had a soluble sodium content of .76 m.e. per 100 grams of soil, whereas in the irrigated comparison, site 43, the sodium content was reduced to .48 m.e. per 100 grams of soil.

Similar trends were found for both Harney and Keith silt loam soils, namely:

1. In the non-irrigated soils the exchangeable sodium percent is highest in the lower horizons.
2. In the irrigated soils the exchangeable sodium is fairly uniform throughout the depth of the soil.
3. The exchangeable sodium in the soil is approaching equilibrium. The equilibrium value is likely to be lower than .6 percent exchangeable sodium in the Harney soil when irrigated with water of comparable quality.

Sears Clay loam, Sites 46 and 47. The soil was sampled from G. Josserand farm in Ford County. The chemical analyses of the irrigated and non-irrigated sites are found in Tables 18 and 19. The soil survey descriptions are found in Tables 48 and 49.

This field has been irrigated from two wells, a shallow well and a deep well. The analyses of the waters are found in Table 2. The water of the shallow well contains 14.2 milliequivalents of soluble salts per liter, and contains 33 percent sodium; whereas, the water of the deep well contains 6.2 milliequivalents of soluble salts per liter and 19.3 percent sodium. The shallow and the deep wells have been used to supply irrigation water for 50 and 10 years respectively. According to the U. S. Salinity Laboratory Standards, the water of the deep well is classified as medium in salinity and low in sodium hazard; whereas, the water of the shallow well is classified as high in salinity and low in sodium hazard. By Kansas State University Soil Testing Standards the waters would be placed in class 1 and 2 respectively.

Salt Content. The data indicate that the electrical conductivity of the saturated extract of the surface horizon of the irrigated soil increased from .508 to .89 millimhos per centimeter. The mean* electrical conductivity of the saturated extract of the irrigated soil increased from .499 to .579 millimhos per centimeter. This increase is slight even though the irrigation water contains 14.2 and 6.21 m.e. of salt per liter from the shallow and the deep well respectively. The soil of the irrigated site is underlain by sands and loamy sands at a depth of 34 inches. The permeability of the subsoil has undoubtedly been a major factor in controlling the build-up of salts in this soil.

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* All means are weighted means.

Table 18. A comparison of the chemical properties of irrigated and non-irrigated Sears clay loam soil located in Ford County.

Depth in inches	Saturation Percentage	Conductivity ECx10^3	pH	Exchangeable cations in m.e. per 100 gr. of soil K	Ca	Mg	Na	Exchangeable Na percentage	Percent of Calcium Carbonate	Exchange Capacity m.e./100 gr. soil	Gypsum content
Location: 1/8 S, .2 mi. E of NW, Sec. 21, T 26S, R 26W								Site 46 irrigated for 10 years			
0-5	42.2	.890	8.2	.92	25.30	6.54	-	-	3.2	26.5	-
5-21	41.1	.685	8.3	.55	29.10	6.50	.07	.31	7.3	22.6	-
21-27	36.0	.712	8.1	.19	26.91	6.55	.06	.42	9.9	14.0	-
27-34	26.2	.685	8.0	.15	24.69	4.63	.08	.91	10.5	6.8	-
34-40	19.7	.468	8.3	.15	4.47	2.21	.03	.97	1.42	3.1	-
40-48	21.8	.349	8.1	.05	26.25	1.08	.03	2.31	.39	1.3	-
48-60	21.6	.387	7.9	.03	1.87	1.08	.02	2.40	.48	.8	-
Location: 1/8 mi. S, NE, Sec. 20, T 26S, R 26W								Site 47 non-irrigated			
0-6	44.3	.508	8.3	1.84	34.34	5.16	.05	.20	4.69	30.0	-
6-17	40.3	.659	8.0	.44	29.81	4.58	.03	.15	4.43	26.5	-
17-26	39.2	.574	7.7	.55	26.15	9.57	.03	.54	9.68	18.4	-
26-37	31.6	.614	8.3	.56	26.20	9.59	.03	.86	10.49	11.5	-
37-49	23.6	.414	7.3	.19	3.72	1.77	.01	2.67	.43	1.5	-
49-60	22.1	.230	8.0	.03	.74	.68	.01	1.33	.29	.8	

Table 19. A comparison of the cations and anions in the saturated extract of irrigated and non-irrigated Sears clay loam soil located in Ford County.

Depth in inches	Water soluble ions m.e./100 gr. soil									
	Cations					Anions				
	K	Ca	Mg	Na	Total	CO_3	HCO_3	Cl	SO_4	Total
					Site 46 irrigated					
0-5	.02	.20	.21	.06	.49	-	.32	.03	.29	.64
5-21	.01	.15	.15	.06	.37	trace	.22	.01	.08	.31
21-27	trace	.09	.10	.07	.26	-	.12	.01	.10	.23
27-34	trace	.06	.07	.05	.18	-	.05	.01	.05	.11
34-40	trace	.03	.04	.03	.10	-	-	.01	.03	.04
40-48	trace	.03	.04	.02	.09	-	.02	-	.06	.08
48-60	trace	.03	.04	.03	.10	-	.04	-	.02	.06
					Site 47 non-irrigated					
0-6	-	.16	.09	trace	.25	trace	.16	-	.18	.34
6-17	-	.19	.11	.02	.32	-	.21	-	.16	.37
17-26	-	.10	.18	.03	.31	-	.13	.01	.03	.17
26-37	-	.06	.16	.03	.25	trace	.09	.01	.03	.13
37-49	-	.03	.11	.10	.24	-	.06	.01	.01	.08
49-60	-	.01	.07	trace	.08	-	.02	-	.02	.04

The major increase in water soluble sodium, magnesium and calcium occurred in the surface horizon of the irrigated site. The mean soluble calcium in the irrigated soil increased over the non-irrigated soil from .08 to .09 m.e. per 100 grams of soil, the mean water soluble magnesium in the irrigated site decreased from .12 to .09 m.e. per 100 grams.

Sodium Content. The exchangeable sodium percentage increased slightly from a mean of 1.10 in the non-irrigated to 1.22 in the irrigated soil. This increase in exchangeable sodium in the irrigated soil amounted to a mean of only .021 m.e. per 100 grams of soil. The water soluble sodium increased from a mean of .02 in the non-irrigated soil to .04 m.e. per 100 grams of soil in the irrigated site.

It is interesting to note that the increase or decrease in the soluble cations, the exchangeable sodium, and the exchangeable sodium percentage are all very small. It is doubtful whether the productivity of this soil will decrease if irrigation is continued.

Silty Clay Loam from V. Carlyle Farm in Meade County, Sites 48 and 49. The chemical analyses of the irrigated and non-irrigated sites are found in Tables 20 and 21. The soil survey descriptions are found in Tables 50 and 51 in the appendix. The soils of the irrigated and non-irrigated sites were similar except that the non-irrigated site contained no calcium carbonate in the A_1 horizon. This difference could not be attributed to the irrigation water. The analyses indicate that the variation of the lime content in the irrigated and non-irrigated sites is too large to be attributed to the irrigation water.

This field has been irrigated from a well since 1927. The water has an electrical conductivity of 412 micromhos per centimeter and a sodium percent

Table 20. A comparison of the chemical properties of irrigated and non-irrigated silt clay loam located on V. Carlyle farm in Meade County.

Depth in inches	Saturation Percentage	Conductivity ECx10³	pH	Exchangeable cations in m.e. per 100 gr. of soil				Exchangeable Na percentage	Percent of Calcium Carbonate	Exchange Capacity m.e./100 gr. soil	Gypsum content
				K	Ca	Mg	Na				
Location:	200'E & 100'S of N¼, corner, Sec. 19, T 30S, R 26W							Site 48 irrigated for 31 years			
0-5	47.9	.858	8.0	2.33	23.78	5.17	1.46	8.58	.03	17.0	-
5-10	52.6	.715	8.3	2.20	44.07	4.93	1.59	7.95	.9	20.0	-
10-18	53.4	.635	8.5	1.91	61.87	5.20	2.51	12.55	3.43	20.0	-
18-29	50.0	.837	8.1	1.96	61.67	6.94	2.37	16.06	3.59	14.8	-
29-37	48.7	.953	8.2	1.77	59.88	6.94	2.40	12.72	3.48	18.9	-
37-46	48.5	1.803	7.9	1.71	32.16	6.63	2.28	12.16	-	18.8	-
46-54	50.6	5.720	7.7	1.48	44.42	4.87	1.99	11.70	-	17.0	6.5
54-60	45.6	5.720	7.8	1.50	35.00	4.91	2.01	12.00	-	16.7	-
Location:	200'S & 100'W of the N4 corner, Sec. 19, T 30S, R 26W							Site 49 non-irrigated			
0-6	43.4	.953	8.1	2.54	18.56	3.54	1.08	7.08	-	15.3	-
6-12	50.1	.673	8.1	2.39	23.82	3.56	1.08	6.64	-	16.3	-
12-22	47.5	.903	7.9	1.49	59.71	4.42	1.47	9.48	4.13	15.5	-
22-32	49.1	.817	8.1	1.52	59.80	.90	1.84	9.81	5.18	18.8	-
32-40	52.4	.408	8.2	1.53	59.94	.90	1.61	8.58	3.68	18.8	-
40-51	50.0	.686	7.8	1.49	60.87	.70	2.08	12.23	4.29	17.0	-
51-60	50.8	.536	7.9	1.50	54.41	.50	2.07	13.35	7.46	15.5	-

Table 21. A comparison of the cations and anions in the saturated extract of irrigated and non-irrigated silt clay loam located on V. Carlyle farm in Meade County.

Depth in inches	Water soluble ions m.e./100 gr. soil									
	Cations					Anions				
	K	Ca	Mg	Na	Total	CO_3	HCO_3	Cl	SO_4	Total
					Site 48 irrigated					
0-5	.05	.22	.07	.04	.38	-	.41	.05	.11	.57
5-10	.04	.18	.07	.05	.34	trace	.43	.07	.09	.59
10-18	.04	.14	.07	.09	.34	trace	.35	.09	.09	.53
18-29	.04	.13	.06	.13	.36	-	.18	.05	.22	.45
29-37	.03	.12	.06	.20	.41	-	.31	.12	.17	.60
37-46	.04	.21	.11	.32	.68	-	.13	.10	.97	1.20
46-54	.07	1.32	.37	.61	2.37	-	.12	.41	2.53	3.06
54-60	.05	1.00	.33	.59	1.97	-	.11	.12	2.32	2.55
					Site 49 non-irrigated					
0-6	.08	.20	.08	.02	.38	-	.50	.04	.21	.75
6-12	.06	.18	.06	.02	.32	-	.35	.03	.15	.53
12-22	.03	.29	.08	.03	.43	-	.35	.02	.19	.56
22-32	.03	.20	.09	.04	.36	-	.27	.14	.10	.51
32-40	.02	.06	.05	.03	.16	-	.06	.05	.08	.19
40-51	.03	.13	.06	.07	.29	-	.13	.06	.25	.44
51-60	.02	.09	.03	.08	.22	-	.11	.05	.18	.34

of 11.7. According to U. S. Salinity Laboratory Standards the water is classified as medium in salinity and low in sodium hazard. The Kansas State University Testing Laboratory would rank the water as class 1.

Salt Content. The mean electrical conductivity of the saturated extract of the irrigated soil was 2.1 millimhos per centimeter. This was higher than the electrical conductivity of the non-irrigated soil by a mean of 1.3 millimhos per centimeter. The conductivity of the irrigated site was 5.72 millimhos per centimeter in the C_2Ca and C_3 horizons. This conductivity is sufficiently high and the sodium content is low enough so that these horizons would be classified as saline. The B_{22} horizon of the irrigated site has an electrical conductivity of .837 millimhos per centimeter and an exchangeable sodium percentage of 16, thus it would be classified as non-saline alkali horizon. The physical condition of a non-saline alkali soil is likely to be very poor. Due to the high zeta potential of sodium, the soil colloids may disperse. If this happens, aeration and water movement will be poor.

Sodium Content. The exchangeable sodium percentage of the irrigated site increased from a mean of 9.98 to 12.27 percent. It is interesting to note that the exchangeable sodium percentage is initially high in all the horizons of the non-irrigated site. The data indicate also that the exchangeable sodium in the irrigated soil increased from a mean of 1.67 to 2.15 m.e. per 100 grams of soil. The water soluble sodium also increased in the irrigated site from a mean of .04 to .26 m.e. per 100 grams of soil. The maximum accumulation of sodium was in the C_2Ca and C_3 horizons of the irrigated soil.

The gypsum content of the C_2Ca and C_3 horizons of the irrigated site was 6.5 and 4 m.e. per 100 grams of soil. Even the gypsum seemed to have no appreciable effect in decreasing the sodium content of these horizons. The high sodium content of both the irrigated and non-irrigated sites suggests that only limited leaching took place in this soil under either dry land or irrigated conditions. According to Wilcox, water classified as medium in salinity and low in sodium hazard is not likely to cause sodium accumulation in a well drained soil. Since sodium did accumulate in the irrigated soil, this further supports the idea that only limited leaching took place. The silt loam surface horizon and the fine textured silty clay loam B_{21} horizon contribute to this condition.

It would be wise to follow further change in this soil very carefully. It is possible that additional horizons in this soil could be converted to an alkali condition if the sodium content continues to build up. Improvement of the drainage conditions and adequate leaching would likely reduce the sodium content of the soil because of the water quality is good and has a low sodium content.

Richfield-like Silt Loam, Sites 50 and 51. The soil was sampled from the L. Chappel farm in Meade County. The chemical analyses of the irrigated and non-irrigated sites are found in Tables 22 and 23. The soil survey descriptions are found in Tables 52 and 53 in the appendix.

This field has been irrigated from a well since 1951. The electrical conductivity of water is 380 micromhos per centimeter and the water contains 18.5 percent sodium. The water quality according to the U. S. Salinity Laboratory Standards classification is medium in salinity and low in sodium hazard. According to the classification of the Kansas State University Soil Testing Laboratory, the water is class 1.

Salt Content. Analyses show some differences between the irrigated and non-irrigated sites even though this soil has been irrigated only six years.

Table 22. A comparison of the chemical properties of irrigated and non-irrigated Richfield-like silt loam located in Mead County

Depth in inches	Saturation Percentage	Conductivity $EC \times 10^3$	pH	Exchangeable cations in m.e. per 100 gr. of soil K	Ca	Mg	Na	Exchangeable Na percentage	Percent of Calcium Carbonate	Exchange Capacity m.e./100 gr. soil	Gypsum content
Location 1/8 mi. W & 100'S of NE, Sec. 28, T 30S, R 30W corner								Site 50 irrigated for 6 years			
0-6	44.6	1.56	8.0	1.49	11.83	.06	1.02	9.95	-	10.3	-
6-12	47.6	.76	7.8	1.04	14.08	.07	1.04	9.04	-	11.5	-
12-18	49.2	.73	7.8	1.10	20.07	.15	1.43	9.22	-	15.5	-
18-25	47.2	.59	7.9	1.15	19.37	.32	1.06	6.83	-	15.5	-
25-32	48.8	.51	7.9	1.40	60.87	.46	1.47	9.48	3.79	15.5	-
32-39	45.0	.55	8.1	1.53	50.14	.71	1.82	12.05	1.44	25.1	-
39-51	50.9	.44	8.0	1.50	60.93	.71	2.44	11.61	7.06	21.0	-
51-60	48.4	.86	8.0	1.50	56.93	.71	1.80	8.57	4.10	21.0	-
Location: .2 mi. W & 50' N of SE, Sec. 21, T 30S, R 30W corner								Site 51 non-irrigated			
0-5	38.7	.46	8.3	1.72	12.43	.09	1.49	9.77	-	15.3	-
5-9	43.1	.39	8.2	1.15	14.93	.09	1.10	6.47	-	17.0	-
9-15	43.9	.40	8.1	1.04	17.17	.21	1.77	8.74	-	20.3	-
15-23	42.0	.40	8.2	.79	28.42	.33	1.10	5.43	-	20.3	-
23-31	40.9	.40	8.1	1.16	39.68	.47	1.86	8.20	4.19	22.7	-
31-40	45.6	.46	7.9	1.23	40.41	.21	1.61	7.57	4.32	21.3	-
40-54	49.8	.52	8.2	1.35	37.46	.47	2.27	11.20	6.08	20.3	-
54-60	47.1	.52	8.4	1.41	34.45	.98	2.84	14.56	3.39	19.5	-

Table 23. A comparison of the cations and anions in the saturated extract of irrigated and non-irrigated Richfield-like silt loam located in Meade County.

Depth in inches	Water soluble ions m.e./100 gr. soil									
	Cations					Anions				
	K	Ca	Mg	Na	Total	CO_3	HCO_3	Cl	SO_4	Total
					Site 50 irrigated					
0-6	.06	.17	.08	.09	.40	-	.20	.11	.09	.40
6-12	.03	.17	.07	.07	.34	-	.30	.03	.11	.44
12-18	.02	.18	.07	.07	.34	-	.26	.01	.09	.36
18-25	.02	.13	.05	.05	.25	-	.22	.02	.09	.33
25-32	.02	.13	.04	.03	.22	-	.14	.04	.06	.24
32-39	.02	.11	.04	.04	.21	-	.10	.06	.09	.25
39-51	.02	.07	.04	.06	.19	-	.09	.04	.08	.21
51-60	.03	.07	.04	.08	.22	-	.08	.08	.09	.27
					Site 51 non-irrigated					
0-5	.03	.07	.03	trace	.13	trace	.11	.02	.07	.20
5-9	.02	.07	.03	trace	.12	-	.11	.03	.08	.22
9-15	.01	.08	.04	trace	.13	-	.08	.03	.08	.19
15-23	trace	.08	.04	trace	.12	-	.05	.02	trace	.07
23-31	.01	.07	.03	.03	.14	-	.06	.03	trace	.09
31-40	.02	.09	.04	.04	.19	-	.10	.01	.09	.20
40-54	.02	.04	.03	.13	.22	-	.09	.07	.12	.28
54-60	.01	.05	.02	.16	.24	trace	.09	.05	.12	.26

The electrical conductivity of the saturated extract increased from a mean of .453 in the non-irrigated site to .714 millimhos per centimeter in the irrigated site. The main increase in the conductivity of the irrigated site was in the top horizon where the conductance increased from .46 to 1.56 millimhos per centimeter. Water soluble calcium increased from a mean of .66 in the non-irrigated to 1.14 m.e. per 100 grams soil in the irrigated site.

Sodium Content. The exchangeable sodium percentage in the irrigated soil increased from a mean of 9.14 in the non-irrigated soil to 9.73 in the irrigated site. The data indicated that there was no difference in the level of water soluble sodium in the irrigated and non-irrigated sites. It is interesting to note that the soluble sodium and exchangeable sodium were distributed evenly in the irrigated site as compared to the non-irrigated site where they were present in highest concentration in the lower two horizons.

On the whole there was very little difference between the chemical analyses of the irrigated and non-irrigated sites, partly due to the short time of irrigation.

Silty Clay Loam from W. Clark farm in Barton County, Sites 65 and 66. The chemical analyses of the irrigated and non-irrigated sites are found in Tables 24 and 25. The soil survey descriptions are found in Tables 54 and 55 in the appendix.

This field has been irrigated from a well since 1937. The electrical conductivity of the water was 990 micromhos per centimeter and the sodium content 34.8 percent. According to the U. S. Salinity Laboratory Standards, the water is high in salinity hazard and low in sodium hazard, and according to the standards of the Kansas State University Soil Testing Laboratory it is class 2 water. The water also contains sufficient bicarbonate so that the

Table 24. A comparison of the chemical properties of irrigated and non-irrigated silt clay loam located on W. Clarke farm in Barton County.

Depth in inches	Saturation Percentage	Conductivity ECx10^3	pH	Exchangeable cations in m.e. per 100 gr. of soil				Exchangeable Na percentage	Percent of Calcium Carbonate	Exchange Capacity m.e./100 gr. soil	Gypsum content
				K	Ca	Mg	Na				
Location:	80 rods E of NW, Sec. 23, T 9S, R 14W corner							Site 65 irrigated for 23 years			
0-7	35.9	1.265	8.1	.77	13.48	2.48	.17	1.03	1.01	16.5	-
7-18	32.5	1.265	8.0	.73	13.47	.16	.26	2.08	1.48	12.5	-
18-22	34.1	1.265	8.1	.63	15.00	1.91	.57	3.45	1.56	16.5	-
22-30	39.4	.88	8.3	.79	44.85	1.96	.83	3.86	4.14	21.5	-
30-50	53.5	1.396	8.4	1.59	49.64	4.72	1.67	4.17	4.74	40.0	-
50-65	48.1	1.306	8.6	1.27	39.79	3.52	1.42	4.23	3.76	33.5	-
Location:	80 rods E of NW, Sec. 23, T 9S, R 14W corner							Site 66 non-irrigated			
0-9	42.9	1.84	6.4	1.55	13.95	2.51	.10	.60	-	16.5	.05
9-18	40.8	1.19	7.0	.96	15.12	2.52	.23	1.24	-	18.5	-
18-24	37.5	1.499	7.5	.88	16.78	2.47	.18	.97	1.40	18.5	.05
24-27	38.6	1.499	7.5	1.08	18.30	3.00	.22	.98	1.58	22.5	-
27-50	47.1	.963	7.8	1.72	29.76	4.52	.80	2.46	2.67	32.5	-
50-68	45.5	2.130	7.6	1.34	44.69	3.99	1.32	4.32	4.00	30.5	-

Table 25. A comparison of the cations and anions in the saturated extract of irrigated and non-irrigated silt clay loam located on the W. Clarke farm in Barton County.

Depth in inches	Water soluble ions m.e./100 gr. soil									
	Cations					Anions				
	K	Ca	Mg	Na	Total	CO_3	HCO_3	Cl	SO_4	Total
					Site 65 irrigated					
0-7	.03	.27	.14	.08	.52	-	.35	.03	.21	.59
7-18	.02	.28	.09	.11	.50	-	.16	.05	.19	.40
18-22	.02	.25	.08	.23	.40	-	.19	.04	.12	.35
22-30	.01	.15	.04	.18	.24	-	.15	.05	.12	.32
30-50	.03	.36	.15	.40	.62	trace	.34	.07	.27	.68
50-65	.03	.21	.11	.38	.73	trace	.20	1.05	.31	1.56
					Site 66 non-irrigated					
0-9	.10	.55	.11	.02	.78	-	.32	.10	.04	.46
9-18	.04	.38	.11	.02	.55	-	.17	.02	.02	.21
18-24	.04	.47	.15	.04	.70	-	.27	.03	.06	.36
24-27	.04	.45	.12	.07	.68	-	.27	.03	.04	.34
27-50	.03	.24	.10	.20	.57	-	.18	.01	.11	.30
50-68	.03	.31	.13	.55	1.02	-	.17	.01	.09	.27

sodium percent possible as defined by Eaton is equal to 100 percent.

Salt Content. The mean electrical conductivity of the irrigated site was 1.27 millimhos per centimeter; whereas, that of the non-irrigated site was 1.49 millimhos per centimeter. Irrigation decreased the electrical conductivity of irrigated site by a mean of .12 millimhos per centimeter. This indicates that sufficient leaching has been accomplished on this soil to keep the salts at a low level. The soluble calcium decreased in the irrigated soil from a mean of .35 m.e. per 100 grams of soil in the non-irrigated soil to .27 m.e. per 100 grams of soil in the irrigated site.

Sodium Content. The exchangeable sodium percentage increased from a mean of 2.35 in the non-irrigated soil to 3.41 in the irrigated soil. This corresponds to an increase of .36 m.e. of exchangeable sodium per 100 grams of soil.

The soluble sodium increased from a mean of .23 in the non-irrigated soil to .27 m.e. per 100 grams in the irrigated site. This change is very slight, but coupled with a decrease in soluble calcium was evidently sufficient to cause the slight increase in the percent exchangeable sodium. The exchangeable sodium was distributed uniformly in the irrigated site while in the non-irrigated site it was most concentrated in the lower horizons.

The A_1p and A_c horizons of the non-irrigated soil contained .05 m.e. of gypsum per 100 grams of soil. The gypsum content of these two horizons was too little to effect the sodium content in the soil.

Silt Loam from W. Clarke Farm, Barton County, Sites 67 and 68. The chemical analyses of the irrigated and non-irrigated sites are found in Tables 26 and 27. The soil survey descriptions are found in Tables 56 and 57 in the appendix.

Table 26. A comparison of the chemical properties of irrigated and non-irrigated silt loam located on W. Clarke farm in Barton County.

Depth in inches	Saturation Percentage	Conductivity ECx10^3	pH	Exchangeable cations in m.e. per 100 gr. of soil				Exchangeable Na percentage	Percent of Calcium Carbonate	Exchange Capacity m.e./100 gr. soil	Gypsum content
				K	Ca	Mg	Na				
Location: 1/6 mi. S & 120' W of E¼ corner, Sec. 22, T 19S, R 14W								Site 68 irrigated 23 years			
0-11	43.4	2.248	7.9	1.27	15.75	5.81	.45	2.43	1.53	18.5	.05
11-21	49.0	1.557	8.1	1.28	17.06	5.8	.50	2.44	1.80	20.5	-
21-32	47.9	1.124	8.1	1.29	33.44	5.88	.90	3.00	3.87	30.0	-
32-44	42.5	1.156	8.3	1.22	33.49	5.89	.91	3.46	3.53	25.0	-
44-60	41.7	1.265	8.4	1.10	26.06	5.29	1.20	5.33	2.79	22.5	-
Location: 1/6 mi. S & 120' W of E¼ corner, Sec. 22, T 19S, R 14W								Site 67 non-irrigated			
0-11	36.3	1.840	6.7	1.18	8.98	3.43	.60	5.22	-	11.5	-
11-19	53.6	2.248	7.8	1.45	14.17	6.16	2.12	11.45	1.1	18.5	-
19-30	50.6	4.048	7.6	1.13	34.53	6.12	3.08	10.80	3.60	28.5	-
30-42	46.3	10.120	8.0	1.00	34.30	5.09	3.17	11.52	2.98	27.5	2.75
42-57	42.3	10.120	7.7	.95	18.44	5.04	3.54	14.16	2.65	25.0	.10

Table 27. A comparison of the cations and anions in the saturated extract of irrigated and non-irrigated silt loam located on the W. Clarke farm in Barton County.

Depth in inches	Water soluble ions m.e./100 gr. soil									
	Cations					Anions				
	K	Ca	Mg	Na	Total	CO_3	HCO_3	Cl	SO_4	Total
					Site 68 irrigated					
0-11	.05	.80	.19	.15	.47	-	.37	.16	.05	.58
11-21	.04	.44	.20	.25	.93	-	.33	.06	.13	.52
21-32	.03	.31	.12	.22	.68	-	.20	.05	.09	.34
32-44	.02	.26	.11	.21	.60	trace	.20	.04	.09	.33
44-60	.02	.19	.08	.30	.59	-	.24	.03	.10	.37
					Site 67 non-irrigated					
0-11	.07	.27	.19	.21	.74	-	.17	.06	.03	.26
11-19	.05	.35	.21	.88	1.49	-	.40	.15	.13	.78
19-30	.04	.34	.25	1.54	2.17	-	.30	.95	.07	1.32
30-42	.07	1.30	.93	3.70	6.00	-	.12	2.63	.14	2.89
42-57	.05	.68	.33	2.96	4.02	-	.15	3.10	.60	3.85

This field has been irrigated from the same well which supplies water to site 65. According to the U. S. Salinity Laboratory Standards the water is high in salinity hazard and low in sodium hazard, and according to Kansas State University Soil Testing Laboratory Standards it is class 2 water.

Salt Content. Irrigation for 23 years decreased the electrical conductivity of the saturated extract of the irrigated soil. The electrical conductivity of the soil decreased sharply from a mean of 5.95 in the non-irrigated site to 1.45 millimhos per centimeter in the irrigated soil, indicating that leaching of salts has taken place. The C_1 and C_2 horizons of the non-irrigated site had a conductivity of 10.1 millimhos per centimeter. Accordingly, these horizons would be classified as highly saline. The C_2 horizon in the non-irrigated soil has an exchangeable sodium percentage of 14.2, which is almost great enough so that this horizon would be classified as a saline-alkali horizon.

The concentration of all the water soluble cations decreased in the irrigated site. Calcium decreased from a mean of .62 to .37 m.e. per 100 grams of soil and magnesium decreased from a mean of .40 to .13 m.e. per 100 grams of soil.

Sodium Content. The exchangeable sodium percentage decreased from a mean of 10.9 in the non-irrigated soil to 3.52 in the irrigated soil after 23 years of irrigation. The soluble sodium also decreased in the irrigated soil from a mean of 2.02 in the non-irrigated soil to .23 m.e. per 100 grams in the irrigated soil.

It is important to note that irrigation of site 68 decreased the exchangeable sodium percentage from 10.9 to 3.52; whereas, irrigation of site 65 with the same water increased the exchangeable sodium percentage from 2.35 to 3.4.

Evidently the exchangeable sodium in both the irrigated soils is approaching equilibrium with the sodium in the water. It appears that the equilibrium exchangeable sodium percent will be near 3.5 percent.

Clay Loam Soil From the L. Hopp and J. Hughes Farm, Sites 69 and 70. The soil from site 69 was sampled from L. Hopp farm in Ellsworth County, while site 70 was sampled from the adjacent J. Hughes farm in McPherson County.

The chemical analyses of the irrigated and non-irrigated sites are found in Tables 28 and 29. The soil survey description of the sites are found in Tables 58 and 59 in the appendix.

This field has been irrigated from the Smoky Hill River* since 1955. The water has an electrical conductivity of 650 micromhos per centimeter and a sodium content of 38 percent. According to the U. S. Salinity Laboratory Standards, this water is classified as medium in salinity and low in sodium hazard , but according to the standards at Kansas State University Soil Testing Laboratory, the water is ranked as class 1 water.

Salt Content. In this particular field very little change that can be attributed to the application of irrigation water have occurred due to the short time of irrigation. There was practically no difference in the electrical conductivity of the saturated extract of the two sites. The irrigated

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* The analyses of the water was obtained from the Kansas Board of Health, Division of Sanitation, Topeka, Kansas. The quality of the river water fluctuates depending on the flow. During months when the river is high, the quality of the water improves due to the dilution of the salt content in the water of the river. During those months when the river is low, the water becomes more concentrated. It is during late June, July, August and September that irrigation is practiced in Kansas, consequently, the quality during these months was determined by taking the average of the salt content of the water during June, July, August and September for three years - 1957, 1958, and 1959.

Table 28. A comparison of the chemical properties of irrigated and non-irrigated clay loam located on L. Hopp and J. Hughes farms in Ellsworth and McPherson counties.

Depth in inches	Saturation Percentage	Conductivity $EC \times 10^3$	pH	Exchangeable cations in m.e. per 100 gr. of soil				Exchangeable Na percentage	Percent of Calcium Carbonate	Exchange Capacity m.e./100 gr. soil	Gypsum content
				K	Ca	Mg	Na				
Location:	400' W & 200' S of NE, Sec. 1, T 17, R 6 corner							Site 69 irrigated 4 years			
0-6	40.1	2.248	7.9	1.02	43.23	1.31	.30	1.53	10.29	19.5	.05
6-17	46.6	1.265	8.1	.87	45.98	1.21	.41	1.70	13.01	24.0	-
17-27	58.5	1.306	8.1	1.02	49.61	1.81	.44	1.21	12.54	36.5	-
27-37	49.6	1.065	8.1	1.47	53.40	1.83	.47	1.24	8.61	38.0	-
37-43	47.6	.987	8.3	1.22	49.69	1.71	.28	.93	9.72	30.0	-
43-52	42.5	.88	8.4	.98	44.74	1.72	.13	.52	2.61	25.0	-
52-60	42.5	.83	8.3	.98	44.73	1.72	.14	.65	11.32	21.5	-
Location:	700' E & 500' S NW, Sec. 6, T17, R 5 corner							Site 70 non-irrigated			
0-6	40.0	1.212	8.0	1.26	44.48	1.59	.20	.76	10.23	26.0	.05
6-15	45.8	1.176	7.9	1.04	46.80	1.08	.08	.28	12.51	28.5	.05
15-30	49.0	1.538	8.0	1.29	59.12	1.56	.15	.42	9.21	35.5	.05
30-42	51.3	1.111	8.1	1.33	56.83	1.56	.10	.26	8.38	37.5	.05
42-52	47.8	.816	8.3	1.29	57.07	1.83	.10	.33	12.76	30.5	-
52-66	39.0	.741	8.3	.85	49.73	1.34	.05	.26	11.75	19.0	-

Table 29. A comparison of the cations and anions in the saturated extract of irrigated and non-irrigated clay loam located on the L. Hopp and J. Hughes farms in Ellsworth and McPherson counties.

Depth in inches	Water soluble ions m.e./100 gr. soil									
	Cations					Anions				
	K	Ca	Mg	Na	Total	CO_3	HCO_3	Cl	SO_4	Total
					Site 69 irrigated					
0-6	.05	.52	.06	.07	.70	-	.33	.03	.07	.43
6-17	.03	.27	.04	.16	.50	-	.22	.02	.10	.34
17-27	.03	.39	.06	.17	.65	-	.31	.03	.05	.39
27-37	.03	.35	.04	.10	.52	-	.22	.02	.04	.28
37-43	.03	.31	.04	.09	.47	-	.21	.01	.05	.27
43-52	.02	.26	.03	.04	.35	-	.17	.02	.03	.22
52-60	.02	.27	.03	.03	.35	-	.15	.02	.02	.19
					Site 70 non-irrigated					
0-6	.04	.52	.03	.02	.61	-	.48	.06	.16	.60
6-15	.03	.60	.04	.02	.69	-	.32	.03	.08	.43
15-30	.03	.88	.06	.02	.99	-	.48	.02	.06	.56
30-42	.04	.67	.06	.02	.79	-	.25	.02	.05	.32
42-52	.03	.43	.04	.02	.52	-	.24	.01	.05	.30
52-66	.02	.27	.03	.02	.34	-	.15	.01	.03	.19

site had a mean electrical conductivity of 1.19 millimhos per centimeter; whereas, the mean electrical conductivity of the non-irrigated site was 1.10 millimhos per centimeter.

The water soluble calcium in the irrigated site decreased from a mean of .57 to .33 m.e. per 100 grams of soil. Water soluble magnesium did not show any change in the two sites.

Sodium Content. The exchangeable sodium increased from a mean of .11 in the non-irrigated soil to .36 m.e. per 100 grams in the irrigated site. This corresponds to an increase in percent in the exchangeable sodium from a mean of .36 to 1.13 respectively. There has been a constant increase in the sodium content of the irrigated soil in the upper horizons. According to Gapon's equation the exchangeable sodium percent might reach a value of 2.85 at equilibrium. It is evident that under adequate drainage, the productivity of the soil would not be impaired due to sodium accumulation.

Ulysses Silt Loam, Sites 30 and 31. The soil from site 30 was sampled from A. Dyck farm in Grant County, while site 31 was sampled from D. Williams farm in Grant County.

The chemical analyses of the irrigated and non-irrigated sites are found in Tables 30 and 31. The soil survey descriptions of the sites are found in Tables 60 and 61 in the appendix.

This field has been irrigated since 1941 from two wells, an old well and a new well. Table 2 indicates that there was very slight difference in the chemical analysis of the waters from the two wells. The electrical conductivity of the new well and the old well are 772 and 769 micromhos per centimeter respectively, and the sodium content of the new and old well is 31.7 and 29.9 percent respectively. The water in both of the wells would be ranked by

Table 30. A comparison of the chemical properties of irrigated and non-irrigated Ulysses silt loam located in Grant County.

Depth in inches	Saturation Percentage	Conductivity $EC \times 10^3$	pH	Exchangeable cations in m.e. per 100 gr. of soil K	Ca	Mg	Na	Exchangeable Na percentage	Percent of Calcium Carbonate	Exchange Capacity m.e./100 gr. soil	Gypsum content
Location: NW¼, SW¼, Sec. 8, T 28, R 38								Site 30 irrigated for 17 years			
0-7	39.6	.551	8.3	1.60	36.14	5.95	.71	2.89	3.06	24.5	-
7-12	44.2	.816	8.0	1.30	54.81	4.55	.48	1.78	11.79	27.0	-
12-24	43.8	.632	8.0	1.23	51.14	5.30	.48	2.04	10.86	23.5	-
24-40	44.2	.612	8.1	1.53	51.17	5.30	.68	3.32	10.45	20.5	-
40-60	43.8	.739	8.3	2.12	49.92	5.29	.53	2.59	10.19	20.5	-
Location: SE¼, SE¼, Sec. 7, T 28, R 38								Site 31 non-irrigated			
0-5	35.2	.816	8.3	1.84	41.05	2.41	.11	.51	3.35	21.5	-
5-11	48.1	.584	8.1	1.05	58.54	2.57	.11	.42	9.02	26.0	-
11-18	43.6	.687	8.1	.99	59.76	3.57	.19	.78	11.14	24.5	-
18-34	40.6	1.030	7.8	.98	58.52	4.07	.11	.47	11.09	23.5	-
34-60	40.1	.466	8.1	1.60	51.18	5.33	.19	.81	8.22	23.5	-

Table 31. A comparison of the cations and anions in the saturated extract of irrigated and non-irrigated Ulysses silt loam located in Grant County.

Depth in inches	Water soluble ions m.e./100 gr. soil									
	Cations					Anions				
	K	Ca	Mg	Na	Total	CO_3	HCO_3	Cl	SO_4	Total
					Site 30 irrigated					
0-7	.02	.11	.05	.04	.22	trace	.15	.06	.10	.31
7-12	.02	.19	.07	.08	.36	-	.12	.13	.07	.32
12-24	.02	.11	.07	.08	.28	-	.08	.03	.09	.20
24-40	.02	.08	.07	.08	.25	-	.10	.02	.15	.27
40-60	.03	.08	.08	.09	.28	trace	.09	.03	.19	.21
					Site 31 non-irrigated					
0-5	.03	.20	.04	trace	.09	-	.12	.06	.07	.25
5-11	.02	.21	.05	trace	.28	-	.13	.04	.07	.24
11-18	.01	.24	.05	.01	.31	-	.12	.06	.04	.22
18-34	.02	.23	.05	.01	.31	-	.07	.03	.02	.12
34-60	.02	.07	.04	.03	.16	-	.08	.02	.03	.13

the U. S. Salinity Laboratory Standards as high in salinity and low in sodium hazard, and according to the standards at the Kansas State University Soil Testing Laboratory the water in both wells would be ranked as class 1 water.

Salt Content. The mean electrical conductivity of the saturated extract of the irrigated and non-irrigated soils were .668 and .683 millimhos per centimeter respectively, indicating very little difference in the salt content of the two soils. This indicates that the water soluble salts did not accumulate in the irrigated soil, denoting that adequate leaching had been accomplished.

The water soluble calcium in the irrigated soil decreased from a mean of .16 to .10 m.e. per 100 grams of soil. The soluble magnesium did not show any change in the two sites.

Sodium Content. The exchangeable sodium percentage increased from a mean of .65 in the non-irrigated soil to 2.64 in the irrigated soil after 17 years of irrigation corresponding to an increase from .15 to .58 m.e. of exchangeable sodium per 100 grams of soil respectively. The water soluble sodium increased in the irrigated soil from an average of .02 to .08 m.e. per 100 grams of soil.

All the changes reported for this soil are very small in magnitude. The productivity of this soil has remained unimpaired by either salt or sodium though the water is classed high in salinity and low in sodium hazard by the U. S. Salinity Laboratory Standards. However, it is always advisable when irrigating the soil to allow excess water to percolate through the soil to remove the salt which is added by the irrigation water.

Clay Loam Soil from Osborne County, Sites 35 and 36. Site 35 was sampled from W. Robinson farm and site 36 was sampled from L. Bohm farm, both of which

Table 32. A comparison of the chemical properties of irrigated and non-irrigated clay loam soil located on W. Robinson and L. Bohm farms in Osborne County.

Depth in inches	Saturation Percentage	Conductivity $EC \times 10^3$	pH	Exchangeable cations in m.e. per 100 gr. of soil				Exchangeable Na percentage	Percent of Calcium Carbonate	Exchange Capacity m.e./100 gr. soil	Gypsum content
				K	Ca	Mg	Na				
Location: E½, NW¼, Sec. 27, T 7, R 11								Site 35 irrigated for 17 years			
0-13	34.8	.508	8.3	.61	13.14	2.60	.21	1.35	1.45	15.5	-
13-20	35.2	.653	8.3	.61	51.08	2.59	.20	.98	4.82	20.5	-
20-42	36.3	.799	8.3	.86	51.06	3.08	.09	.42	5.94	21.5	-
42-53	32.5	.870	8.3	1.03	51.09	3.58	.15	.83	4.99	18.0	-
53-68	33.4	.979	8.4	1.35	53.62	3.96	.28	1.47	5.10	19.0	-
Location: W½, NW ¼, Sec. 27, T 7, R 11								Site 36 non-irrigation			
0-17	32.5	.502	8.2	.74	13.86	1.97	.99	6.39	1.45	15.5	-
17-22	32.4	.384	8.2	.49	47.38	1.23	.11	.71	3.54	15.5	-
22-39	34.0	.384	8.3	.74	51.15	1.97	.19	1.27	7.28	15.0	-
39-51	37.3	.404	8.4	1.06	47.41	1.96	.99	5.50	5.71	18.0	-
51-68	31.3	.502	8.4	1.30	47.43	3.34	.13	.76	5.74	17.0	-

Table 33. A comparison of the cations and anions in the saturated extract of irrigated and non-irrigated clay loam located on W. Robinson and L. Bohm farms located in Osborne County.

Depth in inches	Water soluble ions m.e./100 gr. soil									
	Cations					Anions				
	K	Ca	Mg	Na	Total	CO_3	HCO_3	Cl	SO_4	Total
					Site 35 irrigated					
0-13	trace	.11	.02	.04	.17	trace	.08	.03	.06	.17
13-20	trace	.17	.03	.05	.25	trace	.09	.03	.04	.16
20-42	.01	.19	.04	.03	.27	trace	.06	.03	.20	.29
42-53	.02	.16	.04	.05	.27	trace	.07	.04	.18	.29
53-68	.02	.13	.04	.08	.27	trace	.07	.05	.21	.33
					Site 36 non-irrigated					
0-17	.01	.14	.03	.01	.19	-	.12	.02	.09	.23
17-22	trace	.12	.02	.01	.13	-	.10	.02	.08	.20
22-39	.01	.10	.03	.01	.15	-	.09	.01	.06	.16
39-51	.01	.09	.04	.01	.15	trace	.09	.01	.07	.17
51-68	.02	.07	.03	.04	.16	trace	.07	.02	.06	.15

are located in Osborne County. The chemical analyses of the irrigated and non-irrigated soil are found in Tables 32 and 33. The soil survey descriptions are found in Tables 62 and 63 in the appendix.

The soil has been irrigated since 1940 from the Solomon River near Downs, Kansas. The electrical conductivity of the water was 613 micromhos per centimeter, and the sodium content was 24.4 percent. According to the U. S. Salinity Laboratory Standards, the water quality* of the Solomon River is likely to be medium in salinity and low in sodium hazard. According to Kansas State University Soil Testing Laboratory standards, the water is classified as class 1 water.

Salt Content. The electrical conductivity of the saturated extract increased from a mean of .446 in the non-irrigated soil to .779 millimhos per centimeter in the irrigated site.

The water soluble calcium and magnesium in both the irrigated and non-irrigated soils did not differ appreciably.

Sodium Content. The exchangeable sodium percentage decreased from a mean of 3.13 in the non-irrigated soil to .95 in the irrigated soil. This corresponds to a decrease from .51 to .15 m.e. per 100 grams of soil in exchangeable sodium respectively. The greatest decrease in exchangeable sodium percentage occurred in the A_1P horizon where exchangeable sodium decreased from 6.39 in the non-irrigated soil to 1.35 m.e. per 100 grams in the irrigated soil.

It is likely that the productivity of the irrigated field will not drop due to continued irrigation under ordinary conditions.

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* The analysis of the water was obtained from the Kansas Board of Health, Division of Sanitation, Topeka, Kansas. The average was taken for June, July, August, and September of the years 1958 and 1959.

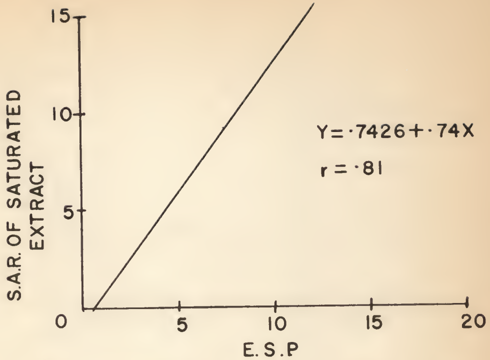

Figure 5. The relation between the sodium adsorption ratio of saturated extract and the exchangeable sodium percentage of soils of Western Kansas.

The Relation Between the Sodium Adsorption Ratio and the Exchangeable Sodium Percentage of the Saturated Extract. Figure 5 shows the relation between exchangeable sodium percentage and the sodium adsorption ratio of the saturated extract excluding site numbers 48, 49, 50 and 51. When sites 48, 49, 50 and 51 were excluded, the correlation coefficient between the exchangeable sodium percentage and the sodium adsorption ratio of the remaining soils increased to .81. This is significant at the 0.001 percent level. Excluding sites 48, 49, 50 and 51, the correlation between the exchangeable sodium percentage in the soil and the sodium adsorption ratio of the saturated extract in the non-irrigated soil was .84 as compared to .68 in the irrigated soils. The difference between the two correlations is significant to the 0.001 percent level. Lewis and Juve (12) also found a better correlation between the exchangeable sodium and the sodium adsorption ratio in non-irrigated soils as compared to irrigated soils.

Due to the abnormal behavior of sites 48, 49, 50 and 51, the correlation coefficient between the exchangeable sodium percentage in all the soils and the sodium adsorption ratio of the saturated extract was only .44. This is significant at the .01 percent level.

The mean exchangeable sodium of site numbers 48 and 50 was 12.27 and 9.73 percent respectively as compared to percentages of .8 and .97 estimated from Gapon's equation. The exchangeable sodium content of the non-irrigated site numbers 49 and 51 is 9.98 and 9.14 percent respectively. This is a higher sodium content than the other non-irrigated sites. The salt content of the irrigated site numbers 48 and 50 is building up even though the water quality used on both sites was class 1. It is likely then, that the drainage system of site numbers 48, 49, 50 and 51 is poor.

Estimating the Exchangeable Sodium Percentage Using Gapon's Equation. Gapon's equation (10) has been used to estimate the exchangeable sodium percentage that would develop in a well drained soil when in equilibrium with an irrigation water of a given salt and sodium content. The equation is as follows:

$$E.S.P. = \frac{(Kg)(Na)(100)}{\frac{T.SC - Na}{2} + (Na)(Kg)}$$

Where, Kg = Gapon's constant, a value of .015 was used.
T.S.C. = Total soluble salts in the irrigation water, m.e. per liter.
Na = Amount of sodium in the irrigation water, m.e. per liter.
E.S.P. = Estimated exchangeable sodium percent in the soil.

Table 34 shows the exchangeable sodium percentage estimated from Gapon's equation compared to the actual exchangeable sodium percentage in the soil. It is interesting to note that except for sites 48 and 50, the values calculated from Gapon's equation were very close to the actual exchangeable sodium percent in the soil. The largest difference was 1.77 percent in site numbers 69 and 70. Gapon's equation over-estimated the exchangeable sodium percentage in six sites and under-estimated the exchangeable sodium percentage in seven sites.

Table 35 shows the relation between the exchangeable sodium percent in the non-irrigated sites compared to the exchangeable sodium percent estimated from Gapon's equation for the non-irrigated soils. Except for sites numbers 49, 51 and 67, the value of the exchangeable sodium percentage calculated for the non-irrigated soils using Gapon's equation were close to the actual exchangeable sodium percentage in the non-irrigated soil. Data in Tables 34 and 35 show that if Gapon's equation gives a close estimate of the exchangeable sodium percentage in the non-irrigated soil then it is likely that it will also give a close estimate of the exchangeable sodium percentage in the soil after it is irrigated. The one exception to this is in site 67 and site 68 where the actual exchangeable sodium percentage and the exchangeable sodium percentage estimated from Gapon's equation is poorly correlated in the dryland site but is well correlated in the irrigated site.

SUMMARY

A laboratory study was conducted to determine the effects of known quality waters on soils in Western Kansas. Soils that were considered to be well drained soils were sampled from Ford, Gray, Meade, Thomas, Logan, Wallace, Barton, Ellsworth, and McPherson counties. A non-irrigated and an irrigated

Table 34. A comparison between the actual exchangeable sodium percentage in the irrigated soils and the exchangeable sodium percentage estimated from Gapon's equation.

Site Number	40	42	46	48	50	52	57	58	60	65	68	69	30	35
Actual E.S.P.*	0.79	0.14	1.22	12.27	9.73	1.0	0.91	1.82	1.75	3.41	3.52	1.13	2.64	0.95
E.S.P.* Using Gapon's Equation	0.80	0.8	1.21	0.8	0.97	1.23	1.19	1.4	1.23	2.24	2.24	2.84	1.95	1.46

* E.S.P. - Exchangeable sodium percentage.

Table 35. A comparison between actual exchangeable sodium percentage in non-irrigated soils and exchangeable sodium percentage estimated from Gapon's equation.

Site Number	41	43	47	49	51	53	56	59	61	66	67	70	31	36
E.S.P.* of Non-irrigated Soil	4.88	.29	1.1	9.98	9.14	.96	1.0	2.21	3.0	2.35	10.85	.36	.65	3.13
E.S.P.* Using Gapon's Equation	3.97	2.59	.58	.75	1.43	.91	.75	1.36	3.10	3.17	1.26	.28	.41	.53

* E.S.P. - Exchangeable sodium percentage.

soil of the same type were sampled from the 14 sites chosen. A soil paste was prepared and extracted. After extraction the electrical conductivity and the amount of calcium, magnesium, sodium, potassium, chloride, sulfate, carbonate and bicarbonate were determined. Exchangeable calcium, magnesium, potassium and sodium were also determined.

The water sampled was analyzed for the same cations and anions as was determined for the soil. The electrical conductivity of the waters varied from 380 to 1414 micromhos per centimeter.

The exchangeable sodium in the soils ranged from a mean of .14 to 12.27 percent. The exchangeable sodium percentage was decreased by irrigation in six sites, increased in four sites and not changed appreciably in four sites. On sites 40, 42, 57, 58, 65 and 68 irrigation decreased the exchangeable sodium percentage. The maximum decrease was in site 68 where the sodium decreased from a mean of 5.95 percent in the non-irrigated soil to a mean of 1.45 percent after irrigation. On sites 35, 48, 50 and 60 irrigation increased the exchangeable sodium percentage. The maximum increase was in site 48 where the sodium increased from a mean of 9.98 percent in the non-irrigated to 12.27 percent in the irrigated site. Irrigation did not change appreciably the exchangeable sodium percentage of the sites 30, 46, 52 and 69.

Irrigation increased the soluble salts in site numbers 30, 35, 42, 48, 50, 52 and 57. The maximum increase was in site 48 where the mean electrical conductivity of the saturated extract of the non-irrigated soil was .710 millimhos per centimeter as compared to 2.10 millimhos per centimeter after irrigation. The salt content of site numbers 40, 65, 68 and 69 decreased due to irrigation. The maximum decrease was in site 68 where the mean electrical conductivity of the saturated extract of the non-irrigated soil was 5.95

compared to 1.446 millimhos per centimeter after irrigation. Irrigation did not change appreciably the salt content of sites 46, 58 and 60. It is interesting to note that the increase of salt content of the soil due to irrigation is slight as compared to the amount of salt leached due to irrigation. For instance, in site 52 located on Keith silt loam soil, it is estimated that an average of 2.2 acre-feet of irrigation water are added each year. The estimated amount of salt added in 18 years was 15.71 tons. Calculations show that 15.36 tons of salts were leached from the soil in the same period of time.

The data show that equilibrium is being established between the sodium in the water and the exchangeable sodium in the soil. In the Keith silt loam soils, for example, irrigation reduced the exchangeable sodium of the subsoil from a mean of 3.4 percent in the non-irrigated soil to a mean of 1.50 percent and it increased the exchangeable sodium in the surface soil from a mean of .58 in the non-irrigated soil to a mean of 1.18 percent after irrigation. It is evident that where the exchangeable sodium in the soil exceeds the equilibrium value, irrigation is reducing the sodium, whereas irrigation is increasing the sodium in soils having a sodium content less than the equilibrium value.

Excluding sites 48, 49, 50 and 51 which appeared abnormal in their behavior, a correlation coefficient of .81 existed between the exchangeable sodium percentage and the sodium adsorption ratio of the saturated extract. When sites 48, 49, 50 and 51 were included, the correlation between the exchangeable sodium percentage and the sodium adsorption ratio of the saturated extract dropped to .44.

Traces of gypsum were found in site numbers 66, 68, 69 and 70. In sites 48 and 67 the gypsum content was 6.5, 4 and 2.75, 0.1 m.e. per 100 grams of soil for the lower two horizons respectively. In spite of the gypsum content in sites 48 and 67, the sodium content increased, due to irrigation.

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APPENDIX

Table 36. Soil survey description of (site 52) irrigated Keith silt loam sampled in 1959 by Jacobs and Bell on F. Rikroff farm in Thomas County.

Ap	0 to 6"	Dark grayish-brown (10YR 3.5/2) silt loam, very dark grayish-brown (10YR 2.5/2) when moist; weak fine granular structure; slightly hard dry, friable when moist; noncalcareous; abrupt boundary.
B_{21}	6 to 16"	Dark grayish-brown (10YR 4/2) light silty clay loam, very dark grayish-brown (10YR 3/2) when moist; weak fine and medium subangular blocky structure; hard dry, firm when moist; noncalcareous; clear boundary.
B_{22}	16 to 24"	Grayish-brown (10YR 5/2) light silty clay loam, dark grayish-brown (10YR 4/2) when moist; weak moderate subangular blocky structure; hard dry, firm when moist; calcareous with few fine nests of soft segregated $CaCO_3$ concretions in lower portion; gradual boundary.
C_1	24 to 52"	Pale brown (10YR 6.5/2.5) silt loam, brown (10YR 5.5/3) when moist; weak coarse prismatic structure; calcareous with common fine nests of soft segregated $CaCO_3$ concretions; diffuse boundary.
C	52 to 60"	Very pale brown (10YR 7/2.5) silt loam, pale brown (10YR 6/3 when moist; massive calcareous loessial parent material.

Table 37. Soil survey description of (site 53) non-irrigated Keith silt loam sampled in 1959 by Jacobs and Bell on F. Rikroff farm in Thomas County.

A_1	0 to 7"	Dark grayish-brown (10YR 3.5/2) heavy silt loam, very dark grayish-brown (10YR 3.5/2) when moist; weak fine granular structure; slightly hard dry, moist friable; noncalcareous; clear boundary.
B_{21}	7 to 17"	Dark grayish-brown (10YR 4/2) light silty clay loam, very dark grayish-brown (10YR 3/2) when moist; weak fine and medium subangular blocky structure; hard dry, firm when moist; noncalcareous; clear boundary.
B_{22}	17 to 23"	Grayish-brown (10YR 5/2) heavy silt loam, dark grayish-brown (10YR 4/2) when moist; weak moderate subangular blocky structure; hard dry, friable when moist; calcareous with few fine nests of soft segregated $CaCO_3$ concretions; clear boundary.
C_1	23 to 50"	Pale brown (10YR 6.5/2) silt loam, grayish-brown (10YR 5.5/2.5) when moist; weak coarse prismatic structure; few fine nests of soft segregated $CaCO_3$ concretions; diffuse boundary.
C	50 to 64"	Very pale brown (10YR 7/2.5) silt loam, pale brown (10YR 6/3) when moist; massive calcareous loessial parent material.

Table 38. Soil survey description of (site 56) non-irrigated Keith silt loam sampled in 1959 by Jacobs and Bell on B. Lee farm in Logan County

A_{1p}	0 to 6"	Grayish-brown (10YR 4.5/2) silt loam, dark grayish-brown (10YR 3.5/2) when moist; weak fine granular structure; slight hard dry, moist friable; noncalcareous abrupt boundary.
A_3	6 to 12"	Dark grayish-brown (10YR 3.5/2) light silty clay loam, very dark grayish-brown (10YR 2.5/2) when moist; moderate medium granular; hard dry, friable when moist; noncalcareous; clear boundary.
B_{21}	12 to 22"	Dark grayish-brown (10YR 4/2) light silty clay loam, very dark grayish-brown (10YR 3/2) when moist; moderate fine and medium subangular blocky structure; hard dry, firm when moist; noncalcareous; clear boundary.
B_{22}	22 to 28"	Dark grayish-brown (10YR 4.5/2) light silty clay loam, very dark grayish-brown (10YR 3.5/2) when moist; weak medium subangular blocky structure; hard dry, firm when moist; calcareous; gradual boundary.
C_1	28 to 47"	Very pale brown (10YR 6.5/2) silt loam, light grayish-brown (10YR 5.5/2.5) when moist; weak coarse prismatic structure; soft dry, friable when moist; calcareous; abrupt boundary.
C_{b1}	47 to 60"	Mixed coloration of dark grayish-brown (10YR 3.5/2, dry) and pale brown (10YR 5.7/2.5, dry) silt loam; massive in the lighter colored material and weakly granular in darker colored material; dry soft; friable when moist; calcareous. This horizon is a mixture of parent material and a thin weakly expressed buried A horizon.

Table 39. Soil survey description of (site 57) irrigated Keith silt loam sampled in 1959 by Jacobs and Bell on B. Lee farm in Logan County.

Ap	0 to 8"	Grayish-brown (10YR 5/2) silt loam, dark grayish-brown (10YR 3.5/2) weakly granular and weak fine laminations; slightly hard dry, friable when moist; noncalcareous; abrupt boundary.
A_1	8 to 16"	Dark grayish-brown (10YR 3.5/2) heavy silt loam, very dark grayish-brown (10YR 2.5/2) when moist; moderate fine and medium granular structure; slightly hard dry, friable when moist; noncalcareous; clear boundary.
B_{21}	16 to 26"	Dark grayish-brown (10YR 4/2) light silty clay loam; very dark grayish-brown (10YR 3/2) when moist; weak moderate subangular blocky structure; hard dry, friable when moist; noncalcareous; clear boundary.
B_{22}	26 to 36"	Dark grayish-brown (10YR 4.5/2) light silty clay loam, very dark grayish-brown (10YR 3.5/2) when moist; weak medium subangular blocky structure; hard dry, friable when moist; calcareous; gradual boundary.
C_1	36 to 49"	Pale brown (10YR 6/2.5) silt loam, brown (10YR 5/3) when moist; weak coarse prismatic structure; dry soft, friable when moist; calcareous with few fine nest and threads of soft segregated $CaCO_3$; abrupt boundary.
C_{b1}	49 to 60"	Mixed coloration of dark grayish-brown (10YR 4/2, dry) and pale brown (10YR 5.5/2.5, dry) silt loam. Massive in lighter colored material and weakly granular; dry soft, friable when moist; calcareous. This horizon is a mixture of parent material and a thin weakly expressed buried A horizon in older aged material than the modern solum.

Table 40. Soil survey description of (site 58) irrigated Keith silt loam sampled in 1959 by Jacobs and Hagihara on Theis Brothers farm in Wallace County.

$A_{1}p$	0 to 3"	Dark grayish-brown (10YR 4.5/2) silt loam texture, very dark grayish-brown (10YR 3/2) when moist; weak fine granular to loose structure; compacted; noncalcareous; dry slightly hard; moist friable; grades abruptly to
A_1	3 to 8"	Dark grayish-brown (10YR 4.5/2) silty clay loam texture; very dark grayish-brown (10YR 3/2)when moist; moderate medium subangular blocky to moderate fine subangular blocky structure; noncalcareous; dry hard; moist firm; changes within 2½ inches to
B_{21}	8 to 15"	Dark grayish-brown (10YR 4/1.5) heavy silty clay loam texture; very dark grayish-brown (10YR 3/1.5) when moist; strong coarse subangular blocky to strong fine subangular blocky structure; dry very hard; moist very firm; noncalcareous; clayskins prominent; grades gradually to
B_{22}	15 to 25"	Dark gray (10YR 4/1), silty clay loam texture, very dark brown (10YR 2/2) when moist; strong medium subangular blocky to strong fine subangular blocky structure; clayskins thin; calcareous; dry hard; moist firm; grades clearly to
Cca	25 to 32"	Gray brown (10YR 5/2), heavy silt loam texture; very dark grayish-brown (10YR 3.5/2) when moist; strong coarse subangular blocky to moderate fine subangular blocky structure; dry hard; moist friable; many $CaCO_3$ concretions; grades gradually to C_1. This horizon is a mixture of parent material and buried soils.
C_1	32 to 54"	Light gray (10YR 7/2), silt loam texture, brown (10YR 5/3) when moist; weak medium subangular blocky to weak fine granular; dry slightly hard; moist friable; fine concretions and streaks of $CaCO_3$; calcareous.

Table 41. Soil survey description of (site 59) non-irrigated Keith silt loam sampled in 1959 by Jacobs and Hagihara on Theis Brothers farm in Wallace County.

A_1p	0 to 3"	Dark grayish-brown (10YR 4/2), light silty clay loam, very dark grayish-brown (10YR 3/2) when moist; weak fine granular to loose structure; noncalcareous; grades abruptly to
A_1	3 to 7"	Dark grayish-brown (10YR 4/2), light silty clay loam, very dark gray brown (10YR 2.5/2) when moist; moderate medium subangular blocky to moderate fine subangular blocky structure; dry slightly hard; moist friable; noncalcareous; grades clearly to
B_{21}	7 to 15"	Dark gray brown (10YR 4.5/2), silty clay loam, very dark brown (10YR 2.5/2) when moist; strong medium subangular blocky to moderate fine subangular blocky structure; dry hard; moist firm; clayskins distinct; lower 2" calcareous; grades gradually to
B_{22}	15 to 22"	Grayish-brown (10YR 5.5/2), silty clay loam texture, dark grayish-brown (10YR 4/2) when moist; moderate medium subangular blocky to weak fine subangular blocky structure; dry slightly hard; moist friable; calcareous; few threads of $CaCO_3$; grades gradually to
Cca	22 to 30"	Light gray (10YR 7/2), heavy silt loam texture, gray brown (10YR 5/2) when moist; weak medium subangular blocky to weak fine subangular blocky structure; dry slightly hard; moist friable; calcareous; few soft $CaCO_3$ concretions and many threads; grades clearly to
C_1	30 to 52"	Light gray (10YR 7/2), silt loam texture, brown (10YR 5/3) when moist; weak fine subangular blocky to weak fine granular structure; dry slightly hard; moist friable; few $CaCO_3$ threads; calcareous.

Table 42. Soil survey description of (site 60) irrigated Keith silt loam sampled in 1959 by Jacobs and Bell on W. Mai farm in Wallace County.

A_1	0 to 10"	Dark gray brown (10YR 4/2), silt loam texture, very dark gray brown (10YR 3/2) when moist; moderate medium subangular blocky to weak fine granular structure; slightly calcareous; dry slightly hard; moist friable; clear boundary.
B_{21}	10 to 17"	Gray brown (10YR 5/2), silty clay loam texture, very dark grayish-brown (10YR 3/2.5) when moist; moderate medium subangular blocky to weak fine subangular blocky; slightly calcareous; dry slightly hard; moist friable; grades gradually to
B_{22}	17 to 24"	Dark gray (10YR 4/1), light silty clay loam texture, very dark brown (10YR 2/2) when moist; strong medium subangular blocky to moderate fine subangular blocky; calcareous; dry hard; moist firm; distinct clayskins; grades gradually to
B_{3ca}	24 to 29"	Gray (10YR 5/1), heavy silt loam texture, very dark gray brown (10YR 3/2) when moist; moderate medium subangular blocky to moderate fine subangular blocky; dry slightly hard; moist friable; few $CaCO_3$ concretions and many threads of lime. This horizon had very faint characteristics of a buried horizon. Grades gradually to
C_1	29 to 51"	Pale brown (10YR 6/3), silt loam texture, dark gray brown (10YR 4/2) when moist; weak medium subangular blocky to weak fine subangular blocky; very few threads of $CaCO_3$; dry soft; moist friable; grades diffusely to
C	51 to 60"	Light gray (10YR 7/2) silt loam texture, brown (10YR 5/3) when moist; massive structure; dry soft; moist friable; calcareous.

Table 43. Soil survey description of (site 61) irrigated Keith silt loam sampled by Jacobs and Hagihara on W. Mai farm in Wallace County.

A_1p	0 to 3"	Dark gray brown (10YR 4.5/2) heavy silt loam texture, very dark grayish-brown (10YR 3/2) when moist; weak fine subangular blocky to weak fine granular structure; dry slightly hard; moist friable; noncalcareous; abrupt boundary.
A_1	3 to 11"	Dark grayish-brown (10YR 4/2) silty clay loam texture, very dark gray brown (10YR 2.5/2) when moist; moderate medium subangular blocky to moderate fine subangular blocky; noncalcareous; dry slightly hard; moist friable; changes clearly to
B_{21}	11 to 19"	Dark gray (10YR 4/1), silty clay loam texture, very dark brown (10YR 2/2) when moist; moderate medium subangular blocky to moderate fine subangular blocky; calcareous; dry hard; moist firm; few $CaCO_3$ threads and concretions; changes diffusely to
B_{22}	19 to 26"	Gray brown (10YR 5/2), heavy silt loam texture, very dark grayish-brown (10YR 3/2) when moist; moderate medium subangular blocky to weak fine subangular blocky; dry slightly hard; moist friable; calcareous; changes gradually to
B_{3ca}	26 to 31"	Dark gray (10YR 4.5/1), silt loam texture, very dark gray (10YR 3/1) when moist; weak medium subangular blocky to moderate fine granular; dry soft; moist friable; calcareous; mottling (FIF) caused by decayed root channels. This horizon is a mixture of parent material and a buried soil. Diffuse boundary.
Cca	31 to 37"	Gray brown (10YR 5/1.5), silt loam texture, dark grayish brown (10YR 3.5/2) when moist; weak medium subangular blocky to weak fine granular structure; dry soft; moist friable; calcareous. This horizon is a mixture of parent material and a buried soil. Few $CaCO_3$ threads.
C_1	37 to 56"	Light gray (10YR 7/2), silt loam texture, brown (10YR 5/3) when moist; moderate fine granular structure; calcareous; many threads of $CaCO_3$; grades gradually to
C	56"	Light gray (10YR 7/2), silt loam texture, brown (10YR 5/3) when moist; massive structure; dry soft; moist friable.

Table 44. Soil survey description of (site 40) irrigated Harney silt loam sampled in 1959 by Jacobs and Dodge on H. Spohr farm located in Ford County.

A_1p	0 to 5"	Grayish-brown (10YR 4.5/2 dry; 3/2 moist) silt loam weak fine and medium granular; friable; noncalcareous. Abrupt boundary to
A_3	5 to 10"	Dark grayish-brown (10YR 3.5/2 dry; 2.5/2 moist) silty clay loam (about 34% clay); moderate medium granular firm side of friable; noncalcareous. Gradual boundary to
B_{21}	10 to 16"	Dark grayish-brown (10YR 4/2 dry; 3/2 moist) heavy silty clay loam (about 37% clay); moderate medium subangular blocky; continuous clay films; firm; hard; noncalcareous. Gradual boundary to
B_{22}	16 to 24"	Grayish-brown (10YR 4.5/2 dry; 3.5/2 moist) silty clay (about 42% clay) moderate medium blocky; firm; very hard; distinct continuous clay films; noncalcareous. Gradual boundary to
B_{3ca}	24 to 36"	Light brownish-gray (10YR 5.5/2 dry; 4/2 moist) silty clay loam, (about 35% clay) moderate medium blocky grading to moderate medium subangular blocky in the lower part; moderately friable; hard; calcareous with soft concretions and lime films. Diffuse boundary to
C_1	36 to 47"	Pale brown (10YR 5.5/3 dry; 4/3 moist) silty clay loam weak medium subangular blocky breaking to weak medium granular; friable; calcareous. Gradual boundary to
C_2	47 to 60"	Light brownish-gray (10YR 5.5/2 dry; 3.5/2 moist) silty clay loam augered sample; no structure observed; friable; calcareous.

Table 45. Soil survey description of (site 41) non-irrigated Harney silt loam sampled in 1959 by Jacobs and Dodge on H. Spohr farm located in Ford County.

A_1p	0 to 6"	Dark grayish-brown (10YR 4/2 dry; 3/2 moist), silt loam weak fine and medium granular; friable; noncalcareous. Abrupt boundary to
A_3	6 to 11"	Dark grayish-brown (10YR 3.5/2; 2.5/2 moist) silty clay loam, moderate medium granular; firm side of friable; noncalcareous. Gradual boundary to
B_{21}	11 to 18"	Dark grayish-brown (10YR 4/2 dry; 3/2 moist) heavy silt loam; moderate medium subangular blocky; continuous clay films; firm; hard; noncalcareous. Gradual boundary to
B_{22}	18 to 28"	Grayish-brown (10YR 4.5/2 dry; 3.5/2 moist) silty clay moderate medium blocky; firm; very hard; distinct continuous clay films, noncalcareous. Gradual boundary to
B_{3ca}	28 to 35"	Grayish-brown (10YR 5/2 dry; 4/2 moist) silty clay loam; moderate medium subangular blocky breaking to moderate coarse granular; moderately friable; hard; calcareous with fine soft concretions and lime films. Gradual boundary to
C_1	35 to 46"	Grayish-brown (10YR 4.5/2 dry; 3.5/2 moist) somewhat darker than sample of site 40 at this depth. Texture silty clay loam; augered sample; no structure observed; friable; calcareous. Gradual boundary to
C_2	46 to 58"	Light brownish-gray (10YR 5.5/2 dry; 4/2 moist) silty clay loam; augered sample; no structure observed; friable; calcareous.

Table 46. Soil survey description of (site 42) irrigated Harney silt loam sampled in 1959 by Jacobs and Tomasu on W. Josserand farm in Gray County.

Ap	0 to 6"	Dark grayish-brown (10YR 4/2, 3/2m) light silty clay loam; dry hard; noncalcareous; lower 1 inch moderate medium platy, grades clear to
A_b	6 to 9"	Dark grayish-brown (10YR 4/2, 3/2m) silty clay loam; moderate coarse blocky breaking to moderate fine subangular blocky; dry hard; noncalcareous; grades abruptly to
B_{21}	9 to 13"	Dark grayish-brown (10YR 4/2, 3/2.5m) silty clay loam; compound weak medium prismatic to moderate fine subangular blocky; dry extremely hard; clayfilms patchy; noncalcareous; few worm casts; grades gradually to
B_{22}	13 to 18"	Dark grayish-brown (10YR 4/2.5, 3/2.5m) silty clay loam; compound weak medium prismatic to moderate medium subangular blocky; dry extremely hard; clayfilms continuous; few worm casts; noncalcareous; grades gradually to
B_{2ca}	18 to 26"	Brown (10YR 5/3, 4/3m) silty clay loam; moderate medium to fine subangular blocky; dry hard; calcareous; grades gradually to
B_{3ca}	26 to 35"	Pale brown (10YR 5.5/3, 4/3) silty clay loam; moderate medium to fine subangular blocky; dry hard; few lime concretions; strongly calcareous, grades to
B_b	35 to 56"	Pale brown (5.5/3, 4/3m) silty clay loam moderate very fine subangular blocky, dry hard, calcareous; grades to
C_{ca}	56"	Pale brown (6/3, 5/3m) silty clay loam; weak medium subangular blocky; dry slightly hard; calcareous.

Table 47. Soil survey description of (site 43) non-irrigated Harney silt loam sampled in 1959 by Jacobs and Tomasu on W. Josserand farm in Gray County.

Ap	0 to 5"	Dark grayish-brown (10YR 4/2, 3/2m) light silty clay loam; weakly granular; dry hard; noncalcareous, grades clear to
A_b	5 to 10"	Dark grayish-brown (10YR 4/2; 3/2m) silty clay loam; moderate very fine subangular blocky; dry hard; noncalcareous; grades clear to
B_{21}	10 to 17"	Dark grayish-brown (10YR 4/2, 3/2m) silty clay loam; weak medium prismatic to moderate medium subangular blocky; dry extremely hard; clayfilms patchy; noncalcareous; grades to
B_{22}	17 to 25"	Grayish-brown (10YR 5/2.5, 4/2.5m) heavy silty clay loam; moderate fine subangular blocky; clayfilms patchy; noncalcareous; grades to
B_{2ca}	25 to 32"	Brown (10YR 5/3, 4/3m) silty clay loam, moderate fine subangular blocky; dry extremely hard, clayfilms patchy; few worm casts; calcareous; grades clear to
B_{3ca}	32 to 36"	Pale brown (10YR 5.5/3, 4.5/3m) silty clay loam; moderate fine subangular blocky; dry extremely hard; clayfilms patchy; calcareous with few lime concretions; grades gradually to
B_b	36 to 50"	Pale brown (10YR 5.5/3, 4.5/3m) silty clay loam; moderate very fine subangular blocky, dry hard; calcareous.
C_{ca}	50"	Pale brown (10YR 6/3, 5/3m) silty clay loam; weak medium to fine subangular blocky; dry slightly hard; calcareous.

Table 48. Soil survey description of (site 46) irrigated Sears clay loam sampled in 1959 by Jacobs and Dodge on G. Josserand farm in Ford County.

A_1p	0 to 5"	Dark grayish-brown (10YR 4/1.5 dry; 2/1.5 moist) clay loam; moderate fine and medium granular; friable; weakly calcareous. Abrupt boundary to
A_{12}	5 to 21"	Very dark grayish-brown (10YR 3/1.5 dry; 2/1.5 moist) clay loam; moderate medium granular; firm side of friable; calcareous. Gradual boundary to
AC	21 to 27"	Grayish-brown (10YR 5/1.5 dry; 4/1.5 moist) clay loam, weak medium subangular blocky to moderate medium subangular blocky to moderate medium granular; moderately firm; moderately permeable; slightly mottled with faint brown stains; calcareous. Gradual boundary to
C	27 to 34"	Light brownish-gray (10YR 6/2 dry; 5/2 moist) clay loam; weak fine and medium granular; mottled with strong brown to brownish-yellow stains. Clear boundary to
Cu_1	34 to 40"	Light yellowish-brown (10YR dry; 5/4 moist) loamy fine sand; loose, noncalcareous, mottled with brownish-yellow stains. Gradual boundary to
Cu_2	40 to 48"	Light yellowish-brown (10YR 6/4.5 dry; 5/4.5 moist) fine sand; loose; noncalcareous; mottled with yellowish-brown to dark yellowish-brown stains. Clear boundary to
Cu_3	48 to 60"	Very pale brown (10YR 7/3 dry; 6/3 moist) medium sand; noncalcareous; wet; weak fine brown stains on sand grains.

Table 49. Soil survey description of (site 47) non-irrigated Sears clay loam sampled by Jacobs and Dodge on G. Josserand farm in Ford County.

A_1p	0 to 6"	Dark grayish-brown (10YR 4/1.5 dry; 2.5/1 moist) clay loam; moderate fine and medium granular; friable; weakly calcareous. Abrupt boundary to
A_{12}	6 to 17"	Dark grayish-brown; (10YR 4/1.5 dry; 2.5/1 moist) clay loam; weak medium subangular blocky breaking to moderate medium and fine granular; firm; calcareous. Gradual boundary to
AC	17 to 26"	Grayish-brown (10YR 4.5/2 dry; 3.5/1 moist) clay loam; weak medium subangular blocky to moderate medium granular; firm; moderately permeable; slightly mottled with faint brown stains; calcareous. Gradual boundary to
C	26 to 37"	Light brownish-gray (10YR 5.5/2 dry; 4.5/2 moist) clay loam; weak fine and medium granular; mottled with strong brown to brownish-yellow stains. Clear boundary to
Cu_1	37 to 49"	Light yellowish-brown (10YR 6/4 dry; 5/4 moist) loamy fine sand; loose; noncalcareous; mottled with brownish-yellow stains.
Cu_2	49 to 60"	Very pale brown (10YR 8/3 dry; 5.5/3 moist) medium and coarse sand; noncalcareous; wet; weak fine brown stains on sand grains.

Table 50. Soil survey description of (site 48) irrigated silty clay loam sampled by Jacobs and Dodge on V. Carlyle farm in Meade County.

A_1p	0 to 5"	Grayish-brown (10YR 4.5/1.5 dry; 3/2 moist) heavy silt loam, weak medium and fine granular; friable; noncalcareous. Abrupt boundary to
A_1	5 to 10"	Grayish-brown (10YR 4.5/2dry; 3/2 moist) silty clay loam; weak medium subangular blocky breaking to moderate medium granular; clay films lacking; firm side of friable; calcareous. Gradual boundary to
B_{21}	10 to 18"	Grayish-brown (10YR 4.5/2 dry; 3/2 moist) heavy silty clay loam; moderate medium subangular blocky; firm; clayfilms prominent of thin cross section; calcareous. Gradual boundary to
B_{22}	18 to 29"	Light brownish-gray (10YR 5.5/2 dry; 3.5/2 moist) light silty clay; moderate medium blocky very firm; clayfilms prominent and continuous of thin cross section; calcareous. Gradual boundary to
B_{3ca}	29 to 37"	Light brownish-gray (10YR 5.5/2 dry; 4/2 moist) silty clay loam; moderate medium and fine subangular blocky; firm; clay films patchy of very thin cross section; highly calcareous with fine and medium soft concretions and lime films. Gradual boundary to
C_{1ca}	37 to 46"	Pale brown (10YR 6/3 dry; 4.5 moist) silty clay loam; weak medium and fine granular; friable; calcareous with fine soft concretions and many lime films. Gradual boundary to
C_{2ca}	46 to 54"	Pale brown (10YR 6/3 dry; 4/3 moist) silty clay loam; auger sample; friable; weakly calcareous with impure salt crystals other than carbonate present. Gradual boundary to
C_3	54 to 60"	Pale brown (10YR 5.5/3 dry; 4/3 moist) light silty clay loam; auger sample; friable; weakly calcareous, with a few fine concretions.

Table 51. Soil survey description of (site 49) non-irrigated silty clay loam sampled by Jacobs and Dodge on V. Carlyle farm in Meade County.

A_{1p}	0 to 6"	Grayish-brown (10YR 4.5/1.5 dry; 3/2 moist) heavy silt loam; weak medium and fine granular; friable; noncalcareous. Abrupt boundary to
A_1	6 to 12"	Grayish-brown (10YR 4.5/2 dry; 3/2 moist) silty clay loam; weak medium subangular blocky breaking to moderate medium granular; firm side of friable, noncalcareous. Gradual boundary to
B_{21}	12 to 22"	Grayish-brown (10YR 4.5/2 dry; 3/2 moist) heavy silty clay loam; moderate medium subangular blocky; firm; clayfilms prominent of thin cross section; calcareous. Gradual boundary to
B_{22}	22 to 32"	Light brownish-gray (10YR 5.5/2 dry; 3.5/2 moist), light silty clay; moderate medium blocky; very firm; clay films, prominent and continuous of thin cross section; calcareous. Gradual boundary to
B_{3ca}	32 to 40"	Light brownish-gray (10YR 5.5/2 dry; 4/2 moist) silty clay loam; moderate medium and fine subangular blocky; firm; clayfilm patchy of very thin cross section; few soft lime concretions but soil mass is highly calcareous.
C_{1ca}	40 to 51"	Pale brown (10YR 6/3 dry; 4.5/3 moist) silty clay loam; weak medium to fine granular; friable; calcareous with fine soft concretions and many lime films. Gradual boundary to
C_{2ca}	51 to 60"	Pale brown (10YR 6/3 dry; 4/3 moist) silty clay loam; auger sample; friable; weakly calcareous with few fine soft concretions.

Table 52. Soil survey description of (site 50) irrigated Richfield-like silt loam sampled in 1959 by Jacobs and Dodge on L. Chappel farm in Meade County.

A_{1p}	0 to 6"	Grayish-brown (10YR 4.5/2 dry; 2.5/2 moist) silt loam; weak medium and fine granular; friable; noncalcareous. Clear boundary to
A_1	6 to 12"	Dark grayish-brown (10YR 4/2 dry; 2.5/2 moist) silt loam; weak medium granular, upper 2 inches compacted into moderate medium platy structure; friable; noncalcareous. Gradual boundary to
B_{21}	12 to 18"	Dark grayish-brown (10YR 4/2 dry; 3/2 moist) silty clay loam; weak medium subangular blocky to moderate coarse and medium granular; continuous clay films, thin cross section; firm; hard; noncalcareous. Gradual boundary to
B_{22}	18 to 25"	Grayish-brown (10YR 5/2 dry; 4/2 moist) heavy silty clay loam; moderate medium subangular blocky; very firm; very hard; clay films prominent and continuous; thin cross section; noncalcareous. Gradual boundary to
B_{2ca}	25 to 32"	Grayish-brown (10YR 5/2 dry; 4/2 moist) silty clay loam moderate medium and fine subangular blocky; clay films prominent, thin cross section; firm; hard; calcareous with many fine soft concretions and lime films; noncalcareous. Gradual boundary to
B_{3ca}	32 to 39"	Light brownish-gray (10YR 5.5/2 dry; 4.5/2 moist) silty clay loam; weak medium and fine subangular blocky; firm; calcareous with many fine soft concretions and lime films. Gradual boundary to
C_{1ca}	39 to 51"	Pale brown (10YR 6/3 dry; 4/3 moist) light silty clay loam; augered sample; friable; highly calcareous with many lime films and soft fine concretions. Gradual boundary to
C_{2ca}	51 to 60	Light yellowish-brown (10YR 6/3.5 dry; 4/3 moist) light silty clay loam; auger sample; friable; highly calcareous.

Table 53. Soil survey description of (site 51) non-irrigated Richfield-like silt loam sampled in 1959 by Jacobs and Dodge on L. Chappel farm in Meade County.

A_1p	0 to 5"	Grayish-brown (10YR 4.5/2 dry; 2.5/2 moist) silt loam; weak medium and fine granular; friable; noncalcareous. Clear boundary to
A_1	5 to 9"	Dark grayish-brown (10YR 4/2 dry; 2.5/2 moist) silt loam weak medium granular; friable; noncalcareous. Gradual boundary to
B_{21}	9 to 15"	Dark grayish-brown (10YR 4/2 dry; 3/2 moist) silty clay loam; weak medium subangular blocky to moderate medium granular; continuous clay films, thin cross section; firm; hard; noncalcareous. Gradual boundary to
B_{22}	15 to 23"	Grayish-brown (10YR 5/2 dry; 4/2 moist) heavy silty clay loam; moderate medium subangular blocky; firm; hard; clay films prominent, thin cross section; noncalcareous. Gradual boundary to
B_{2ca}	23 to 31"	Grayish-brown (10YR 5/2 dry; 4/2 moist) silty clay loam; moderate medium and fine subangular blocky; clay films prominent, thin cross section; firm; hard; calcareous with many fine soft concretions and lime films. Gradual boundary to
B_{3ca}	31 to 40"	Light brownish-gray (10YR 5.5/2 dry; 4.5/2 moist) silty clay loam; weak coarse granular breaking to moderate medium granular; firm side of friable; calcareous with many fine soft concretions. Gradual boundary to
C_{1ca}	40 to 54"	Pale brown (10YR 6/3 dry; 4/3 moist) light silty clay loam; augered sample; friable; highly calcareous with many lime films; gradual boundary to
C_{2ca}	54 to 60"	Light yellowish-brown (10YR 6/3.5 dry; 4/3 moist) light clay loam; auger sample; friable; highly calcareous.

Table 54. Soil survey description of (site 65) irrigated silt clay loam sampled in 1959 by Jacobs and Rockers on W. Clarke farm in Barton County.

$A_{1}p$	0 to 7"	Dark gray brown (10YR 4/1.5d: 2/2m) silty clay loam; moderate to weak fine granular; friable; slightly hard; noncalcareous; grades within 3" to
A_1	7 to 18"	Dark gray brown (10YR 4/2d; 3/2m) light silty clay loam; moderate medium granular; friable; hard; worm casts common; porous; noncalcareous; grades to
A_c	18 to 22"	Gray brown (10YR 5/2d: 3/2m) loam; moderate medium granular; friable; slightly hard; few distinct worm casts, noncalcareous; grades within 1" to
C_1	22 to 30"	Pale brown (10YR 6/3d; 3/3m) light silty clay loam; strong coarse granular; friable; slightly hard; worm casts common; many open rootlet channels; calcareous; grades within 3" to
A_{bu}	30 to 50"	Gray (10YR 5/1d; 3/1m) clay, strong fine granular; firm; very hard; threads of gypsum (?); calcareous; no worm casts; grades within 2" to
AC	50 to 65"	Light brownish-gray (10YR 6/2d; 3/2m) silty clay loam; medium fine granular; friable; hard; few fine roots; calcareous.

Table 55. Soil survey description of (site 66) non-irrigated silt clay loam sampled in 1959 by Jacobs and Rockers on W. Clarke farm in Barton County.

0 to 9"	Silty clay loam
9 to 18"	Light silty clay loam
18 to 24"	Heavy loam
24 to 27"	Silty clay loam
27 to 50"	Clay
50 to 68"	Silty clay loam

Remarks: The described profile (site 65 irrigated) had a rather distinct buried A profile at 30-50". The texture was clay and we would expect the permeability to be very slow. The horizon just above contained carbonates while in site 66 non-irrigated, we do not find as thick a calcareous horizon just above the buried A at 27-50".

Table 56. Soil survey description of (site 67) irrigated silt loam sampled in 1959 by Jacobs and Rockers on W. Clarke farm in Barton County.

A_1	0 to 11"	Gray brown (10YR 5/2d; 2/2m) silt loam; weak granular; loose; slightly hard; grades within 1" to
A_3	11 to 19"	Brown (10YR 5/3d; 3/3 moist) silty clay; moderate fine granular; firm; extremely hard; patchy clay film; few very small worm casts; grades within 1" to
C_{ca}	19 to 30"	Pale brown (10YR 6/3d; 5/3m) clay; very weak fine subangular blocky to massive; firm; extremely hard; calcareous; thin patchy clay films; few fine roots; grades within 4" to
C_1	30 to 42"	Very pale brown (10YR 7/3d; 5/3m) silty clay loam; friable; very hard; massive; thick threads of white salts; calcareous; grades to
C_2	42 to 57"	Light gray (10YR 7/2d; 6/3m) clay loam; massive; very friable; slightly hard; weakly calcareous.
	57 to 72"	Same as above, divided for sampling purposes only.

Table 57. Soil survey description of (site 68) non-irrigated silt loam sampled in 1959 by Jacobs and Rockers on W. Clarke farm in Barton County.

0 to 11"
11 to 21"
21 to 32"
32 to 44"
44 to 60"

Remarks: The irrigated site (number 68 irrigated) was not calcareous as high in the profile by about 3" as was the non-irrigated (site number 67). The structure held quite well where texture was heavy. The permeability is estimated at about 0.10" per hour at field capacity on both sites. It is possible some leaching could occur but appears unlikely it would account for all the carbonates missing in the irrigated on (site 68).

All colors were read from Munsell's soil color chart.

Table 58. Soil survey description of (site 69) irrigated clay loam soil sampled in 1959 by Jacobs and Glover on L. Hopp farm in Ellsworth County.

0 to 6"	10YR 2.5/2m. Very dark brown to very dark grayish-brown clay loam compacted from tillage; calcareous with no visible segregated lime; several fine and medium roots; grades within one inch to:
6 to 17"	10YR 2.5/2m. Very dark brown to very dark grayish-brown clay loam with moderate medium and fine granular structure; patchy weak clayskins; calcareous with no visible segregated lime; few fine and medium roots; grades within one inch to:
17 to 27"	10YR 3/1.5m. Very dark gray to very dark grayish-brown silty clay loam with moderate fine subangular blocky structure breaking to moderate fine granular structure; clayskins patchy; calcareous with no visible segregated lime; few fine roots; grades within one inch to:
27 to 37"	10YR 3/1m. Very dark gray light silty clay with moderate medium subangular blocky structure; Prominent continuous clayskins; strongly calcareous; few rootlets; grades within one inch to:
37 to 43"	10YR 3/2m. Very dark grayish-brown silty clay loam with moderate medium subangular blocky structure; strongly calcareous with many soft mycelia and soft spots of segregated lime; texture gets lighter with depth and segregated lime more pronounced with depth.
43 to 52"	10YR 3/1.5m. Very dark gray to very dark grayish-brown heavy clay loam with weak medium subangular blocky structure; peds very porous strongly calcareous with many threads and splotches of segregated lime; few fine rootlets; grades to:
52 to 66"	10YR 3/2m. Very dark grayish-brown clay loam with weak coarse prismatic structure; strongly calcareous with many threads of segregated lime; very porous; material continues few to many feet thick.

Table 59. Soil survey description of (site 70) non-irrigated clay loam soil sampled in 1959 by Jacobs, Glover and Melvin on J. Hughes farm in McPherson County.

0 to 6"	10YR 2.5/2m. Very dark brown to very dark grayish-brown clay loam which has been compacted due to tillage operations; several fine and medium roots; calcareous; grades within one inch to:
6 to 15"	10YR 2.5/2m. Very dark brown to very dark grayish-brown silty clay loam with moderate fine subangular blocky structure which tends to break to moderate fine granular structure; calcareous with no visible segregated lime; few fine roots; grades within one inch to:
15 to 30"	10YR 3/1.5m. Very dark gray to very dark grayish-brown heavy silty clay loam with moderate medium subangular blocky structure; thin nearly continuous clayskins; calcareous with no segregated lime; few fine roots; grades shortly to:
30 to 42"	10YR 3/1m. Very dark gray silty clay with moderate fine irregular angular blocky structure with overlap of peds of 30 to 40%; strongly calcareous with segregated lime visible in the form of soft spots and threads, more pronounced with depth; few fine roots; strong prominent clayskins; grades within one inch to:
42 to 52"	10YR 3/2m. Very dark grayish-brown silty clay loam with weak medium and fine subangular blocky structure which tends to break to moderate fine subangular blocky structure; strongly calcareous with many threads and soft spots of lime; few fine rootlets; grades within one inch to:
52 to 66"	10YR 3.5/2m. Very dark grayish-brown to dark grayish-brown clay loam with weak coarse prismatic structure; nearly structureless appearance; strongly calcareous with many threads and splotches of lime which gets slightly less with depth; few fine rootlets.

Table 60. Soil survey description of (site 30) irrigated Ulysses silt loam sampled in 1959 by Jacobs, Dixon and Dickey on A. Dyck farm in Grant County.

0 to 7"	Dry gray brown (10YR 4/2 dry, 3/3 moist), calcareous light silty loam (about 28% clay), upper part plow layer - lower part, moderate medium to fine granular root hairs; several worm casts, slightly hard to hard; boundary is clear.
7 to 12"	Light brownish-gray (10YR 6/2 dry, 5/2.5 moist), calcareous; light silty clay loam; moderate medium to fine granular; porous; many worm casts; hard to very hard; boundary is gradual.
12 to 24"	Light gray (10YR 7/2 dry, 5.5/2 moist), calcareous; light silty clay loam; some granular structure; almost structureless; massive; porous; some worm casts; porous; hard; about 1% soft lime concretions; boundry is gradual.
24 to 40"	Light gray (10YR 7/2 dry, 5.5/2 moist), calcareous silt loam or light silty clay loam (27% clay); structureless; massive; porous; hard; about 1 to 2% soft lime concretions; boundary is gradual.
40 to 60"	Very pale brown (10YR 7/3 dry, 5/3 moist), calcareous silty clay loam; massive; porous; slightly hard; some lime film.

Table 61. Soil survey description of (site 31) non-irrigated Ulysses silt loam sampled in 1959 by Jacobs, Dixon and Dickey on D. Williams farm in Grant County.

0 to 5"	Grayish-brown (10YR 5/2 dry, 3/2 moist), Calcareous light silty clay loam or silt loam; weak medium to fine granular; few root hairs; few worm casts; slightly hard; boundary is clear.
5 to 11"	Light brownish-gray (10YR 6/2 dry, 4/2 moist) calcareous; light silty clay loam; moderate medium to fine granular (some moderate medium to fine subangular blocky); many worm casts; porous; hard; boundary is gradual.
11 to 18"	Light gray (10YR 7/2 dry, 5/2 moist) calcareous light silty clay loam; moderate medium to fine granular (some moderate medium to fine subangular blocky); many worm casts; porous; hard; boundary is gradual.
18 to 34"	Light gray (10YR 7/2 dry, 5/2 moist), calcareous light silty clay loam moderate medium to fine granular; some weak medium to fine subangular blocky; some worm casts; porous; hard; boundary is gradual.
34 to 60"	Very pale brown (10YR 7/3 dry, 5/3 moist), calcareous; light silty clay loam, weak medium to fine granular; porous; few worm casts; slightly hard.

Table 62. Soil survey description of (site 35) irrigated clay loam sampled in 1959 by Jacobs and Glover on W. Robinson farm in Osborne County.

0 to 6"	10YR 3/1.5m. Very dark grayish-brown clay loam with fine weak granular structure, horizon shows compaction zone due to tillage; noncalcareous; several fine and medium roots; grades within one inch to:
6 to 13"	10YR 4/2m. Dark grayish-brown with small spots of 10YR 3/1m. Very dark gray clay loam with weak medium subangular blocky structure; noncalcareous; few fine and medium roots; grades shortly to:
13 to 20"	10YR 4/2m. Dark grayish-brown light silty clay loam with moderate medium subangular blocky structure; strongly calcareous with a few fine and medium size threads of segregated lime; few fine roots; grades shortly to:
20 to 27"	10YR 3.5/2m. Dark grayish-brown to very dark grayish brown light silty clay loam with moderate medium subangular blocky structure; strongly calcareous with many threads and splotches of lime; few fine roots; grades within two inches to:
27 to 42"	10YR 3.5/2m. Dark grayish-brown to very dark grayish-brown clay loam with weak coarse prismatic structure; strongly calcareous with lime over the faces of peds; few fine roots; grades within one inch to:
42 to 53"	10YR 4/2m. Dark grayish-brown silt loam with weak coarse prismatic structure; strongly calcareous with few fine threads of lime; few fine roots; grades within two inches to:
53 to 68"	10YR 3/2m. Very dark grayish-brown silt loam with very weak coarse prismatic structure; strongly calcareous; few fine roots.

Table 63. Soil survey description of(site 36) non-irrigated clay loam sampled in 1959 by Jacobs and Glover on L. Bohn farm in Osborne County.

0 to 8"	10YR 2.5/2m. Very dark brown to very dark grayish-brown clay loam with weak fine granular structure; horizon shows compaction zone due to tillage in lower part of horizon; few fine roots; grades within one inch to:
8 to 17"	10YR 4/2m. Dark grayish-brown with small spots of 10YR 3/1m. Very dark gray light clay loam to heavy silt loam with weak medium subangular blocky structure tending toward weak fine granular structure; noncalcareous; few fine roots; grades shortly to:
17 to 22"	10YR 4/2m. Dark grayish-brown silt loam with weak fine granular structure; strongly calcareous with several fine and medium threads and soft spots of lime; grades within one inch to:
22 to 30"	10YR 4.5/2m. Dark grayish-brown to grayish-brown silt loam with weak medium subangular blocky structure; strongly calcareous with several fine and medium threads and soft spots of lime; grades within one inch to:
30 to 39"	10YR 4/2m. Dark grayish-brown silt loam with weak medium subangular blocky structure; strongly calcareous with several fine threads and soft spots of lime; few fine roots; grades to:
39 to 51"	10YR 3.5/2. Very dark grayish-brown to dark grayish-brown light silty clay loam with weak medium subangular blocky structure; strongly calcareous with many fine threads of lime; peds coated with lime on vertical faces; few fine roots; grades within one inch to:
51 to 68"	10YR 4.5/2m. Dark grayish-brown to grayish-brown silt loam with weak coarse prismatic structure; strongly calcareous.

THE EFFECT OF KNOWN QUALITY IRRIGATION WATER ON THE CHEMICAL PROPERTIES OF SOILS OF WESTERN KANSAS

by

BADI IBRAHEM NADDIH

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AN ABSTRACT OF A THESIS

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Soils that were considered to be well drained soils were sampled from Ford, Gray, Meade, Thomas, Logan, Wallace, Barton, Ellsworth and McPherson counties. A non-irrigated and an irrigated soil of the same type were sampled from the 14 sites chosen. The sites were sampled by horizons. Analysis for the principal water soluble and extractable ions were made on each soil sample.

The water sampled was analyzed for the same soluble cations and anions as was determined for the soil. The electrical conductivity of the waters varied from 380 to 1414 micromhos per centimeter.

The exchangeable sodium in the soils ranged from a mean of .14 to 12.27 percent. The exchangeable sodium percentage was decreased by irrigation in six sites, increased in four and not changed appreciably in four sites.

The only nonsaline alkali horizon occurred in the B_{22} horizon of site 48.

The salt content in the soils ranged from a mean of .44 to a mean of 5.95 millimhos per centimeter. Irrigation increased the salt content in seven sites, decreased it in four sites, and did not appreciably change it in the remaining three sites. The data show that equilibrium is being established between the sodium in the water and the exchangeable sodium in the soil. Irrigation tended to reduce the exchangeable sodium percentage in those subsoils where the exchangeable sodium percentage was above the equilibrium value. In the top soil of most sites, where the exchangeable sodium percentage was below the equilibrium value, irrigation tended to increase the exchangeable sodium percent.

Except for site numbers 48 and 50, the values of the exchangeable sodium percentage estimated from Gapon's equation were very close to the actual exchangeable sodium percent in the soil. Gapon's equation over-estimated the exchangeable sodium percentage in six sites and under-estimated it in seven sites.

Excluding site numbers 48, 49, 50 and 51 which appeared abnormal in their behavior, a correlation coefficient of .81 existed between the exchangeable sodium percentage and the sodium adsorption ratio of the saturated extract. When sites 48, 49, 50 and 51 were included the correlation between the exchangeable sodium percentage and the sodium adsorption ratio of the saturated extract dropped to .44.